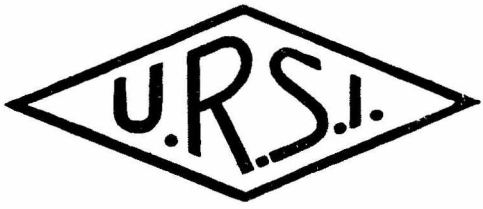
INTERNATIONAL SCIENTIFIC RADIO UNION



Proceedings of the XIIth General Assembly

held in Boulder, Colorado, U. S. A.
from August 22nd to September 5th, 1957

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Part 1

COMMISSION I

On Radio Measurements and Standards

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On Radio Measurements and Standards

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List of Reports and Papers submitted to the Commission

The asterisk indicates reports published in full text in this part.

N°	Titles and Authors
1	C.C.I.R. findings of interest to U.R.S.I., *U.R.S.I. Inf. Bull.*, **100**, 48-81.
83	Frequency (phase) multipliers for measuring devices, M. E. ZHABOTINSKY, U. L. SVERDLOV, Y. I. SVERCHKOV, Institute of Radio Engineering and Electronics, Academy of Sciences of the U.S.S.R.
122*	Report on work carried out in Great Britain during the period 1954-1957, Dr. L. ESSEN.
139*	Report of the Swiss National Committee, Prof. KÖNIG.
156*	Report of the New Zealand National Committee.
165*	Report of the Netherlands National Committee.
184*	Report of the Canadian National Committee.
190*	Report of the German National Committee.
197*	Report of the Japanese National Committe, I. KOGA.
204*	Report of the Polish National Committee.
209*	Report of the French National Committee.
218*	Report of the Swedish National Committee, H. BJÖRKLUND.
222*	Report of the Australian National Committee.
236*	Recommendations of the International Committee on Weights and Measurements to Commission I.
241	Power measurements by film bolometers, J. A. LANE.
242*	Report U. S. Commission I.
255	A fade-cancelling zero beat indicator, R. J. BLUME.
256	Low frequency standards transmissions, W. D. GEORGE.
257	Accuracy of WWV and WWVH, W. C. STICKLER.
258	Status report on microcalorimetric technique, G. F. ENGEN.

Collaboration with the C. C. I. R.

The Plenary Assembly of the C.C.I.R. held in Warsaw in 1957 asked for the collaboration of U.R.S.I. to deal with Recommendation n° 179 (Standard Frequency Transmissions and Time Signals) which is relevant to Commission I.

The complete text of the recommendation was published in Information Bulletin n° 100 (November-December, 1956).

N° 236 = Recommendations of the International Committee on Weigths and Measurements to Commission I

(*Translation*)

Recommendations of the Advisory Committee for the Definition of the Second (1st Session, June 3 and 4, 1957).

RECOMMENDATION 1

The Advisory Committee recommends that the laboratories carrying out the construction of atomic frequency-standards should pursue their study as far as possible, and furnish the most complete data on the results obtained.

RECOMMENDATION 2

The Advisory Committee recommends that such laboratories should organize as soon as possible the comparison of their atomic frequency-standards, may they be of the same type or of different types. It is desirable that these comparisons be made for all the possible combinations.

RECOMMENDATION 3

The Advisory Committee wishes that Commission I of U.R.S.I., at the occasion of the Twelfth General Assembly in Boulder, put into study the comparison of the atomic frequency-standards, congruently with Recommendation 2.

Reports of National Committees

Australia

N° 222. — Report of the National Committee to the Commission

ABSOLUTE DETERMINATION OF THE OHM

A new type of calculable capacitor has been developed in which the capacitance is critically dependent on one length measurement only (1, 2). By this means the electrostatic unit of capacitance should be determined to an accuracy at least comparable to that achieved for the electromagnetic unit of inductance. The recent determinations of the velocity of electromagnetic waves by Essen and others provide a conversion factor of sufficient precision to enable the electrostatic unit to be used as an independent check on the absolute value of the ohm.

Such a project has reached an advanced stage at the Australian National Standards Laboratory.

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Canada

N° 184. — Report of National Commission I

FREQUENCY STANDARDS

A standard of frequency has been established, consisting of eight Essen ring type of crystal oscillators supplemented by G-T cut crystal oscillators. This is a cooperative project since the oscillators are located in three different laboratories in the Ottawa

region. A method of intercomparison of these oscillators using transmission of the fundamental frequency of 100 kc/s over telephone cable has been developed and found to be quite satisfactory. A short time stability of $1 : 10^{10}$ and long term stability of $5 : 10^{10}$ or better has been achieved. The history of these oscillators is known for a period of about three years and their performance is quite satisfactory. The absolute frequency is determined in terms of the astronomical observations of the Dominion Observatory where a Photographic Zenith Telescope is used for this purpose. A programme is to be initiated soon for observations on the moon with a dual rate moon camera.

Comparison of frequency against other national standards is made by observing times of receptions of time signals. Recently measurements have also been made on the 16 kc/s transmission of GBR from Rugby, England, by observing the phase of the received carrier. Useful results have been obtained by both techniques. Intercomparisons show very close agreements between the frequency standards of Great Britain, United States, and Canada.

Construction of a caesium beam apparatus for frequency measurement and standardization is in progress at the National Research Council.

The Dominion Observatory time signals have been transmitted on a 24-hour schedule for many years over the station CHU operating on 3330 kc/s, 7335 kc/s and 14670 kc/s. Clock corrections to the time signals are available on request from the Dominion Observatory, Department of Mines Technical Surveys, Ottawa, Canada. Plans have been drawn up for control of the carrier frequencies of the Station CHU to an accuracy of $1 : 10^8$. This modification is expected to come into effect some time in 1958.

Radio Frequency Measurements

Techniques for measurement of power and attenuation in the frequency range 300 to 30 000 Mc/s are under development at the National Research Council. A circuit for comparison of power levels has been developed. Comparison of nominally equal power levels is possible to an accuracy of 0.1 to 1.0 %.

The velocity of propagation of electromagnetic waves was measured at a frequency of 400 Mc/s using a coaxial cavity. The accuracy was limited by the Q and the boundary effects. Results

in general agreement with the presently accepted value of *c* were obtained.

Microwave spectrometers up to 37 kMc/s have been used, and spectra in the frequency range up to 12 kMc/s have been studied with atomic and molecular beam techniques.

A spectrum scanning equipment has been developed and used by the Department of Transport in the frequency range 1-20 Mc/s in 1 Mc/s bands. It gives both a visual and photographic record of the station occupancy of the frequency band to which it is tuned.

Measurements have been made on radio interference from high voltage power transmission lines, and work on radio interference from corona is under progress.

Techniques for the precision measurement of radio components at RF frequencies are being developed at the National Research Council, which is also engaged in a long-term programme for the absolute determination of several electric, magnetic and electromagnetic quantities.

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France

N° 209. — General Report of the National Committee

(*Translation*)

I. — Frequencies

A. — Frequency standards

Various improvements have been brought to the quartz standard oscillators. One of them consists of using two exciting amplifiers in parallel in order to avoid any stop which may be caused by a failure in the unique conventional amplifier (1). On the other hand the Laboratoire National de Radioélectricité (L. N. R.) has constructed and put into use an experimental standard entirely equipped with transistors (thermostatization included).

Studies are in progress concerning the atomic standards at various university laboratories; the LNR will obtain in the near future a caesium beam standard of commercial type; from now on, comparison measurements have been conducted up to 120 Gc/s for research purposes on certain spectral lines (2).

Using the figures given earlier by L. Essen on the comparison between the caesium beam standard and the astronomical time, N. Stoyko applied the results to the study of the Earth's rotation irregularities. He has also computed the correction to brought to these figures in order to account for the most recent determinations of the provisional uniform time (3).

For intercomparison of standards and time measurements, various designs have been developed : electronic counters, cathode ray oscillographs with multiple rotations of the spot (4), graduated synchronous disks with stroboscopic illumination, all entirely transistorized (5). An application has been made of the pulses given by a magnet passing in front of a coil in the synchronous clocks; the precision obtained is one part in 10^5 sec (6).

In the field of accurate monitoring measurements a receiving frequencymeter with direct indication of the frequency in c/s on decametre wave lengths has been developed at the Measurement Center of the French Department of Posts, Telegraphs and Telephones (7).

Jampierre (8) has made a study of the relative frequency fluctuations of two cavity-stabilized reflex klystrons; various designs led him to a relative accuracy better than one part in 10^{10}.

B. — *Transmissions of frequency standards*

The LNR took part in the quarterly experiences for determining the velocity of propagation of time-signals, organized by Prof. Boella as a consequence of decisions made at The Hague by Sub-Commission IIIc. No transmitter being available at that time, the LNR only made differential measurements of transit times on the paths Rugby-Paris, Torino-Paris, Washington DC-Paris. An oscillographic device giving an accuracy of 10^{-5} sec. has been constructed ; the delays in the receiver were also studied. Results of this work have shown that in certain optimum conditions for reception, the arrival time of signals can be appreciated up to 10^{-5} sec., but that in many cases anomalies of propagation introduce considerable errors. The equipment constructed is now used for daily comparisons between MSF and LNR.

Mrs A. Stoyko (9) has studied the influence of « superpropagation » (i. e. propagation along the longest arc) on the time of transit of time signals. During a period the LNR has made automatic recordings of the received frequency on 5 Mc/s, which have confirmed previous results on the Doppler effect.

As stated in the C.C.I.R. report (n° 66, Warsaw 1956), the LNR began at the end of 1956 experimental transmissions of a standard frequency on 2.5 Mc/s. At first made with a power of 50 W, this transmission is now made with a power of 300 W. Periods of transmission are restricted to diurnal hours and provisionnally to Mondays and Thuesdays ; but in the future they will be extended to every working day. These transmissions are arranged in a sequence of 20 min. durations containing 1 min. modulated at 440 c/s, 9 min. modulated at 1000 c/s, 10 min. of pulses, one every sec. (5 cycles of a signal modulated at 1000 c/s) ; the transmission is stopped during 5 min. every hour. Soon the transmission on 2.5 Mc/s will be preceded and followed by one half-hour period on 5 to 10 Mc/s (alternatively, one day every two days).

This transmitter is called FFH and its geographical coordinates are 48°16′ N and 2°20′ E.

II. — Electromagnetic field strengths

Directive receiving aerials for metre and decimetre wavelengths have been developed by F. Carbenay which include an inductive circuit for field strength measurements by the substitution method.

This inductive circuit is constituted by a relatively short dipole (with respect to the half-wavelength) and feeded by a high frequency generator through an intensity indicator. By its interaction with the directive aerial, this inductive circuit can produce on the receiver the same effect as the electromagnetic field to be measured. A calibration of the directive aerial by means of an electromagnetic field of sufficient intensity to be measurable with a single dipole is thus possible.

M. Mende, K. Rawer and E. Vassy have designed a rocket-borne apparatus for measuring the field strength distribution with height. Two transmitters were used respectively in the range 170-240 kc/s and 600-1000 kc/s. The antenna was constituted by a ferrite rod, placed in a plexiglas cone in front of the rocket.

III. — Impedances

In view of measuring the Q-factor of piezoelectric crystals, H. Mayer developed a method (10) in which the exciting oscillations at the resonant frequency are periodically cut off by means of a vibrator.

In order to be able to take into account the losses in the transmission lines impedance measurements, F. Mayer developed (11) a formula and the corresponding chart giving the corrected VSWR as a function of the measured value of this quantity.

R. Guillien constructed a new impedance diagram (12) giving impedance transformations by translations.

To obtain the parasitic cathode resistance of a tube, P. Sevin made differential measurements of amplitude (13), in which the HF signal and a low frequency signal are successively applied to the control-grid of the tube under examination.

R. Lacoste and G. Giralt have made a systematic survey of all the errors which may occur in the calculation of variable plane air-capacitors, and have established their upper limit as af unction of the mechanical features of the capacitor.

IV. — Dielectric and magnetic materials

In order to improve the sensitivity of permittivity measurements, and to record automatically the results, R. Guillien introduced (15) frequency discriminators.

A. Lebrun brought improvements (16) to permittivity measurements by the voltage-resonance method at a variable temperature, in the frequency range from 0.1 to 50 Mc/s. He has also studied the most appropriate method which should be used at various frequencies in the range from 10 c/s to 50 Mc/s (17).

R. Arnould and A .Lebrun considered (18) the possibility of improving permittivity measurements on centimetre wavelengths of highly lossy dielectrics.

With the development of accurate measurements of small capacitors, R. Libaert constructed (19) a device allowing permittivity measurements of very low lossy materials from 0.1 to 1 Mc/s.

J. Le Bot and S. Le Montagner have established a method implying simple calculations for dielectric measurements at centimetre wavelengths (20) in placing the dielectric shaped as a rod into a wave guide.

V. — Magnetic fields

P. Grivet *et al.* have made measurements of magnetic fields by electronic methods (paramagnetic nuclear or electronic resonance). Since the construction of large accelerators of the Synchrotron type, this question has received considerable attention from a practical point of view. An extended report will be presented to the General Assembly.

VI. — Miscellaneous researches

J. Munier developed (21) a direct reading instrument for antenna gain determinations, based on electrical integration of the squared characteristic function in the assumption of axial symmetry.

R. Olivier constructed (22) a broadband UHF standard generator (2300-4600 Mc/s) using the tube Carcinotron « O ».

R. Rocherolles has made stabilizations of frequencies of a 8 mm reflex klystron and realized (23) a measuring equipment on millimetre wave lengths.

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Germany

N° 190. — Report of Commission I of the National Committee

The following text generally gives reports in the field of time — and frequency — measurements ; there are only few reports concerning the power measurement, the field strength a. s. o.

The present national frequency — and time-standard presented by the quartz clocks (P) of the Physikalisch-Technische Bundesanstalt (PTB) has been described for the first time by A. Scheibe (1) and his collaborators.

In contrary to the former PTR-construction with the Pierce-Miller-circuit, the quartz controlled oscillator has been connected according to Pierce, i. e. with the quartz between anode and grid ; by this means a greater independance of the frequency from the circuit has been attained. The earlier mounting of the rod by means of a string (perlon) has been still improved essentially ; the electrodes are now fixed at the exterior of the evacuated glass bulb containing the quartz. At present there are three of these new quartz clocks in the PTB : P1, P2, P3 ; the acceleration (aging) of these clocks is smaller than 1.10^{-9} of the frequency per month. The frequency variation during days is near by $\pm 5.10^{-11}$ of the

frequency, during a lot of months it is less than $\pm 5.10^{-10}$ of the frequency value concerning the average value of the whole period. The exact value of the frequency can be extrapolated over a period of approximately half a year within a maximal systematical error of $\pm 3.10^{-9}$ of its value, save that astronomical observations are necessary.

The transmitter DCF 77, carrier frequency 77.5 kHz, at Mainflingen near Frankfurt/Main, at present has been completed by two PTB-quartz clocks P4 and P5 ; one of these clocks controls the carrier frequency. At the moment the deviation of the carrier frequency is $\pm 2.10^{-9}$ of its nominal value.

Kettel (2) describes a very good quartz-controlled frequency meter and a quartz generator of high precision.

The heterodyne frequency meter of Kellerer (3) works in the frequency range between 850 and 5000 MHZ and presents a combination of the resonance method and the beat method. The measuring accuracy lies within the order of magnitude of $\pm 10^{-5}$ of the frequency.

Adelsberger (4) describes a simple but very exact wavemeter (« rod wavemeter ») for the range of $\lambda = 3{,}5$ mm up to nearly $\lambda = 1{,}65$ m wavelength. The wavelength meter consists of a tube of brass with silver plating inside which is closed at one side and in which a coaxial internal conductor (« rod ») has to be put in tune. The measuring accuracy in the UHF-range is nearly $1.5.10^{-4}$ of the wavelength.

The frequency microscope of Ohl (5) allows the recording of the relative deviation of two frequencies with high sensitivity. The two frequencies are heterodyned to give pulsations ; a sequence of time markers produced by these pulsations is recorded on a drum type chronograph whose drum frequency is chosen in a certain manner. Frequency deviations in the order of magnitude of $\pm 5.10^{-14}$ of the frequency are easily determined.

Becker (6) investigates the accuracy attainable in measuring an unknown frequency against a know reference frequency by means of frequency multipliers, heterodyne equipment and electronic counters and describes the principal mechanical data of the used set up whose measuring error is at a measuring time of 100 s at favorably located frequencies not more than $1.4.10^{-11}$ of the frequency.

Becker (7) discusses the relationship of so-called series resonance and antiresonance on piezoelectric crystal resonators with the real physical resonances and shows that at these frequencies no physical quantity is at a maximum. The conceptions of series resonance and antiresonance are subsequently extended, the characteristic properties of series resonance and antiresonance are outlined, and criteria are given which allow a clear discrimination to be made between series-resonance and antiresonance oscillators.

Becker (8) reduces great part of the customary crystal oscillator circuits to basic arrangements with an underlying general condition of oscillation. Two categories of circuits can be distinguished and they prove to be series-resonant and parallel-resonant circuits, respectively. Scarcely there can be given an opinion upon worth or unworthy of a circuit.

Kraus (10) describes determination of power by voltage measurements at an artificial consumer and by heat measurements. This concerns instruments which are developed to a certain ripeness by the industry.

According to Elektronik, 4 (11), a terminal resistance (rod of coal-layers), adapted to the characteristic impedance of a coaxial line, thermally destines the high frequency power to be measured. The measuring range is between 20 to 500 mW; the measuring error 1 to 3 %.

Turban (12) has reached a high precision for UHF-measuring circuits by special exact mechanical constructions, smallest tolerances and appropriate fashioning. The exact measuring error is ± 1 %.

Schaffeld and Bayer (13) describe the theory concerning the propagation of electromagnetic waves in circlecylindrical wave guides near the cutoff frequency, and show how a reflex klystron operating near the cutoff wavelength of the wave guide can be stabilized within a variation of $\pm 1.10^{-8}$ of the frequency.

PTB began with the development of measuring equipment to test measuring instruments for field strengths and to measure electrical data of four-poles ultra-short waves range. A large hall is dressed by layers reducing the reflections in order to make measurements at wavelength-interferometers. In the wave range of $\lambda = 1$ cm to $\lambda = 10$ cm it occurs that the reflected high frequency power was reduced at a vertical incidence of the radiated power

between 1.10^{-4} to 1.10^{-5} of the amount. As consequently to the damp and cold summer of the last year the layers could not dry completely it should be expected still a further strong reflection diminution.

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Japan

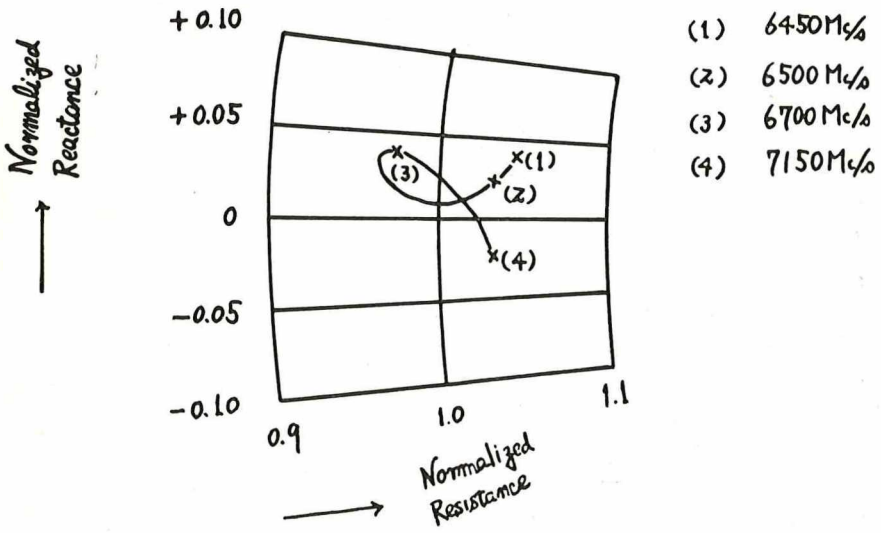
Nº 197. — Report of Commission I of the National Committee

by I. Koga, *Official Member*

1. — Standard of Power Measurement at Microwave Frequencies

Although the comparison of the standards for microwave power measurement is to be made at 3000 and 10 000 Mc/s according to the resolution of Commission I, the Japanese Commission, cooperating with the Institute of Communication Engineers of Japan, tentatively prepared a standard at 6700 Mc/s, because this frequency has been most widely used in Japan.

This standard is a barretter mount made by the Shimada Physical and Chemical Industrial Co. in cooperation with the Anritsu Electric Co., which has no movable element. In order to get a satisfactory performance over a wide frequency band, impedance matching iris and post were placed near the input of the waveguide. Fig. 1



shows the characteristic of input impedance. The efficiency of the barretter mount was measured by impedance method proposed by R. W. Beatty and F. Reggia (*Bureau of Stds Journ. Res.*, **54**, June 1955), and the results obtained at three different institutions (Univ. of Tokyo, Electrical Communication Laboratory of Japanese Telephone and Telegraph Co. and Shimada Physical and Chemical Industrial Co.) were 98.0, 98.6 and 98.3 %, respectively. Therefore the mean value of the calibration factor is about 1.02. The error of measurement was estimated about ± 2 % in total, due to the error in the calibration of the attenuator, in the matching of generator and load, etc. Moreover, it was found that the effect of non-uniformity in the microwave heating along a barretter wire cannot be overlooked, as was pointed out by H. J. Carlin and Max Sucker (*Proc. I. R. E.*, **40**, p. 1042) and discussed later by A. C. Macpherson and D. M. Kerns (*Rev. Sci. Instr.*, **26**, p. 27, 1955). The maximum probable correction for this effect may amount to about 2 % at 10 mW and 1 % at 5 mW.

On the other hand the calibration factor obtained by means of a microwave microcalorimeter at the Electrotechnical Laboratories, Ministry of Trade and Industry was 1.013 ± 0.006, which is in good coincidence with the above mentioned value obtained from the mount efficiency.

After the intercomparison among the Japanese institutions, the Japanese Commission asked Dr. R. L. Smith-Rose in the United Kingdom and Mr. W. D. George in U. S. A. if the international comparison might be possible. However, according the replies from them, it was proved not convenient for them for the time being.

So the Japanese Commission is now preparing duplicate standards at 9375 Mc/s, in cooperation with the Institute of Electrical Communication Engineers of Japan again, because this frequency is also widely used in Japan for radar, and moreover it has been already confirmed that the comparison at this frequency was not convenient for both the United Kingdom and U. S. A.

These standards will be sent to these countries towards the end of August 1957.

2. — Frequency standard

Crystal clocks are generally used as the most precise working standards in our country, and the rate of frequency change is generally less than $\pm 2 \times 10^{-8}$ cycle/sec/day. Crystal vibrators generally used are 3000 kc R_1-cut (called AT-cut in U. S. A.) and 100 kc GT-cut.

Recently several institutions are developing the ammonium molecular clock, and four clocks are now in operation, all of which are controlled by the absorption frequency of the line $J = K = 3$. The source modulation system is used in the two clocks, while Stark modulation and Stark-Zeeman modulation is used respectively in the other two. Comparison of time scales between molecular and astronomical standards has been carried out at Tokyo Astronomical Observatory for these years. Among the four clocks the Stark-Zeeman ammonium clock, designed and operated by K. Shimoda at Tokyo University has shown a fairly constant relation with the astronomical time over a year. The result of the measurement during a period from March to Novembre 1956 based on UT2 was 23,870, 131.05 $\pm$ 0.05 kc/sec. (confidence coefficient : 90 %), that is, the error is $\pm 2 \times 10^{-9}$. Since the frequency shifts to the higher frequency due to the gas pressure of ammonium, the extrapolated value of the frequency at zero pressure was given above.

3. — Determination of the adiabatic elastic and piezoelectric constants of quartz

At the XIth General Assembly I. Koga reported preliminarily on the precision determination of adiabatic elastic and piezoelectric constants of quartz, since those values had not been sufficiently coincident among various authors. According to Koga et al's improved theory, there are three kinds of plane elastic waves in any direction in quartz, and the velocity of each wave is given by $\sqrt{(c/4\rho)}$, where ρ is the density of quartz and c is given by each one of the three real roots of the following equation :

$$\begin{vmatrix} L + \frac{4\pi}{K} A_2 - c & H + \frac{4\pi}{K} AB & G \\ H + \frac{4\pi}{K} AB & M + \frac{4\pi}{K} B^2 - c & F \\ G & F & N - c \end{vmatrix} = 0, \quad (3.1)$$

where :

$$\begin{aligned} L &= l^2 c_{11} + m^2 c_{66} + n^2 c_{44} + 2mnc_{14}, \\ M &= l^2 c_{66} + m^2 c_{11} + n^2 c_{44} - 2mnc_{14}, \\ N &= (l^2 + m^2) c_{44} + n^2 c_{33}, \\ F &= (l^2 - m^2) c_{14} + nl(c_{13} + c_{44}), \\ G &= 2lmc_{14} + nl(c_{13} + c_{44}), \\ H &= 2nlc_{14} + lm(c_{11} - c_{66}), \\ A &= (l^2 - m^2)\varepsilon_{11} - mn\varepsilon_{14}, \\ B &= -2lm\varepsilon_{11} + ln\varepsilon_{14}, \end{aligned}$$

c_{11}, c_{66}, etc. being the adiabatic stiffness constants, ε_{11} and ε_{14} the piezoelectric stress constants, and l, m and n the direction cosines of the direction of wave propagation.

Based on these formulae, c_{hk}'s and ε_{hk}'s are determined by means of the measurement of very high harmonic resonant frequencies of thin quartz plates in various orientations. Since the details are described in a paper submitted to The Physical Review, only some of the results will be shown here.

$$\begin{aligned} c_{11}/4\rho &= 81.957 \pm 0.014, \\ c_{33}/4\rho &= 99.99 \pm 0.11, \\ c_{44}/4\rho &= 54.9861 \pm 0.0061, \\ (c_{13} + c_{44})/4\rho &= 66.250 \pm 0.020, \\ c_{14}/4\rho &= -17.0501 \pm 0.0036, \\ \frac{4\pi}{K} \varepsilon^2_{11}/4\rho &= 0.728 \pm 0.017, \\ \frac{4\pi}{K} \varepsilon^2_{14}/4\rho &= 0.040 \pm 0.017, \\ \frac{4\pi}{K} \varepsilon_{11}\varepsilon_{14}/4\rho &= -0.1696 \pm 0.0076, \end{aligned} \quad (3.2)$$

at 20° C.
(unit : 10^9 cm²/sec²., confidence coefficient : 90 %)

The following table shows the measured values of frequencies (f) and thicknesses (a) together with their products $(af)_{mes}$. They are in good coincidence with the calculated values $(af)_{cal}$ based on (3.1) and (3.2) shown in the last column.

Thus it is no more necessary to postulate, as Atanasoff and Hart did (*Phys. Rev.*, 59, 85, 1941), that the quartz belongs to the rhombic system.

Moreover, the first, the second and the third differential coefficients of $c_{hk}/4\rho$, etc. with respect to temperature at 20° C are also determined, and the frequency-temperature characteristics of X-cut and Y-cut plates calculated thereby proved to be in good coincidence with the experimental results of Atanasoff and Hart.

Orientations	a(mm)	f(kc/s)	$(af)_{mes}$	$(af)_{cal}$
Y (01.0)	3.3788	579.667	1958.58	1958.58
R (01̄.1)	3.9590	625.048	2474.57	2474.57
r' (01.1)	3.6104	462.507	1669.84	1669.85
(02̄.3)	3.6110	704.752	2544.86	2544.85
(02.3)	3.0418	578.731	1760.38	1760.37
(01̄.2)	4.4310	577.777	2560.13	2560.14
(01.2)	3.1590	588.743	1859.84	1859.85
(21̄.1)	2.7724	1152.575	3195.4	3195.3
		767.881	2128.9	2129.3
		662.310	1836.2	1835.7
(42̄.3)	3.4803	945.675	3291.2	3291.0
		586.587	2041.5	2041.8
		546.311	1901.3	1901.4
(21̄.2)	3.4718	959.466	3331.1	3331.0
		616.960	2142.0	2142.2
		530.730	1842.6	1843.1
(21̄.3)	3.6726	906.869	3330.6	3330.5
		626.653	2301.4	2301.4
		500.494	1838.1	1838.5
X (21̄.0)	4.9395	582.097	2875.3	2875.5
	4.9390	582.212	2875.5	2875.5
	3.6510	787.545	2875.3	2875.5
	3.6500	787.790	2875.4	2875.5

Netherlands

N° 165. — National Report to Commission I

An automatic frequency measuring equipment for testing small scale production of crystals with a fundamental frequency up to 10 Mc/s is in use in the laboratory of the Netherlands Postal and Telecommunications Services.

Batches up to 10 crystals are placed in an oven, the temperature of which can be changed from $-20°$ to $+70°$ centigrade. Each crystal is connected to a two-tube series resonance oscillator. The frequency of these oscillators is measured, one after the other with a time difference of 2 seconds. The accuracy is better than $5.10^{-8} \pm 1$ c/s. The principle of the measuring method is described elsewhere. The measured frequencies of a batch are printed in a row on a sheat of paper. At the beginning of a row the temperature of the oven at that moment is also printed. So every 24 seconds a measurement is taken and printed from the same crystal.

The series resistance of the crystals is indicated on meters also. A set of measurements of a batch of 10 crystals in which the temperature is changed from $-10°$ to $60°$ centigrade lasts about 45 minutes.

A frequency measuring equipment for the accurate and fast measuring of the frequency of far-off transmitters has been developed and is now in use in the frequency monitoring department of the receiving station of the Netherlands PTT at Nederhorst den Berg. For the principles of operation reference is made to the literature (1). The range of the special receiver is from 60 kc/s - 31 Mc/s. The accuracy in the band from 4 Mc/s - 31 Mc/s is better than 5 c/s. When the receiver has been tuned to the desired transmitter, the time taken for a measurement is 1 second.

In the broadcast band up to 2 Mc/s the accuracy is better than 0.2 c/s due to the use of a phase discriminator for the automatic

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(1) L. R. M. Vos de Wael, Direct reading frequency measuring equipment for the range 30 c/s-30 Mc/s. *Proc. I.R.E.*, 1952, n° 7, pp. 807-813.

L. R. M. Vos de Wael, Dispositif permettant d'effectuer avec une grande précision des mesures de fréquence dans la gamme 30 Hz-30 MHz et indiquant directement les résultats. *L'Onde électrique*, 32, 1952, n° 305-306, pp. 351-356.

frequency control of the receiver. The time taken for a measurement is then 10 seconds. The main fault on the lower frequencies, being caused by the decimal counter, can further be diminished by prolonging the time of a measurement (e. g. 100 seconds).

The frequency measured is direct reading in 8 digits without any correction being necessary. The measured result can also be printed. Successive measurements from the same transmitter can be printed automatically with a time interval of 3 seconds.

PROBLEMS IN CONNECTION WITH C.C.I.R. WORK

Due to mutual interference great difficulties are often encountered by the reception and the measurements of time signals and standard frequencies.

For instance in the Netherlands the reception of WWV on 5 and 10 Mc/s is severely disturbed by MSF.

In doc. 272 of the VIIIth Plenary Assembly of the C.C.I.R. in 1956 at Warsaw an account is given of some measuring methods and several proposals are made for some alterations in the transmission of time signals and standard frequencies to diminish the difficulties stated.

Special attention of the U.R.S.I. is asked for the recommandations made in doc. 272, chiefly for the points 1, 2, 4, 5 and 6, which are of immediate importance. The remaining recommendations are related to future developments in the number of transmitters. In connection with recommendation 1 the number of transmitters in a limited area (e. g. Western Europe) should not be greater than strictly necessary.

New Zealand

N° 156. — Report of the National Committee

(*a*) WORK ON STANDARD RADIO FREQUENCIES

At the Dominion Physical Laboratory (D.S.I.R.) a low power standard frequency transmission has been set up and since March 1955 has been operating on 2.5 Mc/s from 0100-0400 U. T. each Tuesday. The nominal accuracy is $\pm$ 1 part in 10^7 and it is intended for local use only.

As part of the programme of checking the oscillators for this work, prolonged observations have been made on the 10 Mc/s and 15 Mc/s standard frequency transmissions of WWVH. A paper (1) has been published on this work.

Observations have also been made on the 16 kc/s transmissions from GBR, Rugby, which is not very far from antipodal to New Zealand. Except near sunrise and sunset, and at times of solar flares, the apparent received frequency from this station is constant within a few parts in 10^9. At sunrise and sunset the frequency variation is only as much as $\pm$ 2 parts in 10^8. This has called attention to the possibilities of a world wide frequency standard service using very low frequency waves. The work has been published (2).

(*b*) Radio Measurements

A paper has been published (3) on work done at the Dominion Physical Laboratory on a selective admittance measuring set. Its interest lies in the use of coherent detection for obtaining high selectivity.

(*c*) The Gas Discharge Tube as a Noise Source

Work has been carried out both at Victoria University College and at the Dominion Physical Laboratory on gas discharge tubes as radio noise sources (4).

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Poland

N° 204. — Report of the National Committee

The Polish National Committee has nothing to report in the field of research on instruments for measurement of microwave power, frequency standards, transmission and reception of frequency and time signals.

1. In the field of stabilization of frequency of self-excited generators a new analytical method of interpreting possible instabilities has been developed; the method has been verified by means of measurements and a basis has been created for achievement of an increased frequency stability in systems of this kind (1, 2).

2. In the field of high frequency standards work has been done to execute a high frequency voltage standard and to develop a method of comparing voltages of arbitrary sources with standard voltages. Two independent methods which have been developed both together enable the measurement of voltages in the diapason 1μ V — 1000 V in the range 100 Kc/s — 300 Mc/s (3). In connnection with the above work the electrical properties of thin metal layers have been investigated as stated in the provisional report (4).

3. In the field of new instruments note should be taken of the following :

3.1. Q-meter counting damped oscillations of a circuit (5).

3.2. Special phase detectors as balance indicators in alternating current bridge measurements (6).

3.3. Arrangements for direct measurement of the band width of wireless telegraphy emissions (7). Besides this many authors dealt with improvements in the design of existing instruments or with development of the methods of measurements, for example (8, 9, 10).

4. In the field of measurement of material properties the following have been worked out :

A method of testing the ageing of fluid dielectrics, exspecially insulating oils, by measurement of the loss angle tg δ (11).

Measurements of the properties of ferroelectrics (12), designs of standards of dielectrical loss (13) and various problems (14, 15), have been dealt with.

5. A certain amount of work has been done to wireless measurement techniques. In the field of design of testing instruments, used in nuclear research, several partially original methods and designs have been worked out; the respective papers will be published in the report of the Institute of Nuclear Research.

In the field of precision measurements the work dealt with improvements in the accuracy of bridges (16) and precision measurements of properties of capacitors.

The Polish National Committee does not present individual communiqués within the scope of the activity of the Committee. Instead, a certain number of reprints will be prepared of the more interesting papers in order to render their contents accessible to those whe are interested in them. These reprints will contain ample summaries in English.

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Sweden

Nº 213. — Report of the National Committee

(Hilding BJÖRKLUND)

In the field of Commission I the following work is carried out by the Royal Board of Swedish Telecommunications.

Field strength measurements in the range between about 15 kc/s and 500 Mc/s, atmospheric noise measurements on 45 kc/s and frequency measurements in the range 0-12000 Mc/s.

A new primary frequency standard, type GPO/Airmec, with a short time stability of less than 5.10^{-10} per day and a long time stability of between 1.10^{-7} and 1.10^{-8} a year is under installation.

Measurements of radiation from transmitters, receivers — FM broadcast and television receivers included — and other equipments especially in the VHF range are made.

Switzerland

Nº 139. — Report of the National Committee to Commission I

by Prof. KÖNIG

At the Department of High Frequency Techniques of the Department of Electrical Engineering a method using a bridge was elaborated for the precise measurement of the reflection-coefficient within the K-band ($\lambda = 1.25$ cm) (1).

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United Kingdom

N° 122. — Report on work carried out in Great Britain during the period 1954-1957

by L. Essen

Since 1954 there have been a number of important developments in the field of standards and measurements. These are briefly reviewed in the following sections and a full bibliography of the papers published in the field is appended.

1. — Standards of frequency and time

A caesium standard of frequency and time has been used at the National Physical Laboratory since 1955 to calibrate the quartz working standard (1, 2). The effects of varying the parameters of the design have been thoroughly studied (3) and it has been established that the existing model provides, through the intermediary of quartz clocks, a unit which is known and accurate at all times to ± 2 parts in 10^{10}. It is suggested that the value first determined, 9 192 631 830 c/s, should be adopted as a provisional standard (4) and this value is used at the NPL for monitoring the MSF standard frequency transmissions (5) and for measuring the variations of astronomical time (2). The atomic unit of time and frequency is made available to the Royal Greenwich Observatory and the British Post Office by land-line links, and to a large part of the world by the MSF radio transmissions.

Quartz oscillators have been tested at liquid helium temperatures (6), and a quartz ring oscillator gave evidence of a considerably enhanced performance. Arrangements are being made at the NPL to maintain a ring in continuous operation in a liquide helium bath.

A new drive circuit having improved phase stability has been developed for a high frequency (5 Mc/s) quartz standard (7).

2. — Standard frequency transmissions

The MSF transmissions have been operated throughout the period and the values of frequency have been published in Wireless Engineer (now Electronic and Radio Engineer). A new pamphlet describing the service is being issued (8). The MSF standard

is also used to control the carrier frequency of GBR (16 kc/s) and this transmission and that on 60 kc/s have been used (9) for comparisons between the U. K. and the U. S. A. with a precision exceeding $\pm$ 1 part in 10^9. Details of the transmitting and monitoring arrangements have been published (10, 11, 12). A continuous record of the frequency of one of the transmissions on 2.5, 5.0 or 10 Mc/s is obtained at the NPL, Teddington, at which the reflected wave is received. A great amount of accurate data of the frequency changes due to propagation effects has thus been obtained, but it has not yet been analysed.

In view of recommendation 3 of the XIth General Assembly, note has been taken of the effects of interference from other transmitters. A strong signal is obtained from IBF and at times also from WWV on 5 Mc/s and 10 Mc/s. When the various stations are at comparable strengths direct frequency measurements are interfered with, but this is of little importance as the accuracy is in any case limited by the Doppler variations. Measurements of the time signals are difficult during the periods when one of the carriers is tone-modulated but they can be made during the periods when the carriers are not modulated. The off periods of WWV and MSF enable the signals to be identified and no confusion is caused.

3. — Power measurements

Several new power measuring techniques have been investigated mainly at frequencies of 3 Gc/s (3×10^9 c/s) and above. The application of the Hall effect has been described in more detail (13) and extended to microwave frequencies (14). A method using the mechanical force exerted by the electromagnetic field on a small vane in a resonant cavity (15) has possible systematic errors amounting to seven per cent at a frequency of 3 Gc/s for power levels between 2 and 100 mW. Power levels in this range have also been measured by thermal methods, using resistive films. In one of these (16) a tapered resistive film is placed in a glass cell along the waveguide axes, and the temperature rise is indicated on an air thermometer. The error at 10 Gc/s is less than two per cent. Preliminary experiments using thin transverse films have been reported (17). In this technique, the film is designed and mounted in such a way that powers of 1-100 mW are measured

in terms of a D.C. calibration with an error not exceeding two per cent.

The performance of typical thermistors and bolometers as indicators of absolute power has been investigated at a frequency of 10 Gc/s using a standard calorimeter and a directional coupler (18) and further results on thermistors at frequencies of 50-60 Gc/s have been given in a general survey of millimetre wave techniques (19). In the VHF and UHF bands a coaxial line load has been used for levels up to 1 kW (20). The line is filled with carbon tetrachloride and the inner conductor consists of short sections of thin gold-film resistors. Other equipment developed includes two types of thermistor bridge (21, 22) a microwave thermistor calorimeter (23) and a monitor of received noise factor at microwave frequencies (24).

4. — Field strength measurements

A perturbation method in which a short thin metal rod forms the perturbing element has been developed for the measurement of field-strength (25), the equipment described operating at a frequency of 10 Gc/s. In another method a small spherical bead of dielectric or ferromagnetic material is used for measuring the intensity distribution in a cavity (26).

Details of a receiver for the measurement of aerial gain and directivity at frequencies of 170-220 Mc/s have been given (27) and measurements have been made of the vertical polar diagram of several UHF aerials (28).

5. — Impedance

A new twin T dual admittance bridge has been developed and thoroughly investigated (29). It is a precision instrument having a range of measurement with coaxial systems between 3 and 300 Mc/s, the errors at 200 Mc/s not exceeding 0.2 per cent, on either component of a complex admittance. The circuit used is amenable to the accurate calculation of residual error terms, enables the r. f. conductance of the bridge's internal standard resistor to be established, provides a conductance range of mesurement which is independent of frequency, and provides a mean for the compensation of residuals associated with the series elements and the common earth connection.

A visual impedance matching equipment (30) has been used in the range 80-250 Mc/s and for higher frequencies descriptions of several standing-wave instruments have been given (31, 32, 33). Coaxial resistors in the form of cylindrical films have been investigated (34) and the results show that the impedance is within one per cent of the D. C. resistance with an extremely small phase angle for frequencies in the band 0-3500 Mc/s. Instruments for magnetron Q measurements (35) and for microwave measurements by means of a lossy variable terminations (36) have been described.

6. — Dielectric constant

A number of precise measurements have been made at the NPL. Dry gases and water vapour have been measured at 72 Gc/s (37). The values differ from those obtained at lower frequencies at the NPL in the manner expected from dipole theory. Standard liquids have been investigated from low frequencies up to 9.2 Gc/s. (38). To obtain consistent results with benzene a long drying treatment is necessary, and cyclohexane which is free from this disadvantage is recommended as a standard liquid for measurements of dielectric constant. A wide range of liquids of medium and high loss have been measured by a coaxial line method (39) and a bridge method has been described for the precise measurement of the permittivity of sheet specimens (40). At a Symposium held at the National Physical Laboratory a number of general papers on dielectric measurements were read (41, 42, 43, 44).

An interesting new method of measuring refractive index which has been described (45) makes use of a parallel plate spectrometer. A beam of 1.25 cm waves is directed through the material cut in the form of a prism and the directions of the incident and refracted rays can be located to within 0.25°.

A bridge method of measuring complex permittivities at ten fixed frequencies in the range 30 to 10^6 rad/sec. should perhaps be mentioned (46) as it was published in the U. K. although the work was done in Australia.

7. — Ferrites

A convention on ferrites was held at the I. E. E. on 29th October to 2nd November 1956. A number of papers on measurements included a review of the techniques available for measuring the

properties of ferrite materials at microwave frequencies (47), a theoretical paper on the same subject (48) and a number of more specialised papers (49, 50, 51, 52).

8. — Miscellaneous measurements

An account has been given of the practice adopted at the NPL for the calibration of laboratory standards of inductance (53).

The velocity of radio waves has been determined by an interferometer method (54) and a review of microwave determinations has been published (55). The provisional value obtained is in agreement with that now accepted. A simple radio interferometer for speed measurement, by a Doppler drift method has also been described (56).

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U. S. A.

N° 242. — Report — U. S. Commission I – U.R.S.I.

Review of Developments on Radio Measurement Methods and Standards 1954-1957

Since the XIth General Assembly, significant improvements with respect to frequency standards and radio frequency measurements have been made in the United States. The following represents a group of reviews of the most significant advances. These were prepared by Messrs. W. D. George, H. Lyons, R. G. Fellers, A. B. Giordano, M. Sucher and W. E. Chapin, T. E. Tice and R. H. George.

1. — Frequency and Time Interval Measurements and Standards

A new IRE standard on piezoelectric crystals was published (1). The standard specifies nomenclature and practical methods of measuring the various quantities associated with piezo-electric vibrators.

Research and Development on quartz resonators continued to yield new and useful improvements in the field of frequency control, measurements, and standards. Quartz crystal units which were constant to 3 parts in 10^{10} per day at 65° C and had a minimum Q of four million at this temperature were developed (2).

Investigations were underway on the aging rates and other characteristics of quartz crystal units when operated at relatively constant temperatures in the range from about 2° K up to about 250° K. Theoretical considerations and measurements indicated a substantial reduction in aging at the lower temperatures ; also, at certain low temperatures the Q was substantially increased and the temperature coefficient of frequency was reduced (3, 4).

Standard frequencies broadcast from WWV and WWVH were increased in accuracy from a part in 50 million to a part in 100 million ; also the stability of the frequencies broadcast was increased to about 1 part in a billion at WWV, and to 5 parts in a billion at WWVH. The time signals at both stations were changed to agree closely with the newly defined UT2, determined by the U. S. Naval Observatory (5).

The operation of an experimental standard frequency transmitting station on 60 kc/s was commenced by the National Bureau of Standards Boulder Laboratories. An important use of the transmission has been the regular intercomparison at Cruft Laboratory Harvard University of the U. S. A. and the UK standard frequency broadcasts (6).

A better understanding was had of measuring instruments and techniques and improved instruments were made available (7, 8). A practical limitation to sensitivity in the instrumentation with which high precision oscillators were compared was not yet reached.

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Great progress has been made in the field of primary, atomic standards of frequency and time. This work has proceeded principally along three directions.

First, the line widths associated with collision and Doppler large broadening in gases resulted in intensive efforts to find techniques leading to high-Q spectrum lines. The original absorption methods were therefore largely superseded except for work of Shimoda in Japan. The first high-Q method was the cesium, atomic beam, magnetic resonance method developed at the National Bureau of Standards. This resulted in a preliminary value for the cesium, zero-field transition frequency of 9192.63 188 $\pm$ 0.00003 Mc/s. The cesium beam method was further developed at M. I. T. and the National Company resulting in the first commercially available atomic clock and frequency standard named the « atomichron » with a stability of 5 parts in 10^{10}. Further refinements of this method are under study.

Second, a new beam technique using ammonia was developed at Columbia University. This resulted in operation of a Maser (an acronym for Microwave Amplification by Stimulated Emission of Radiation) which used the emission of ammonia rather than absorption to make a self-excited oscillator at the frequency of the 3.3. NH_3 transition. The Maser consists of an atomic sample, which is not in thermal equilibrium, contained in a cavity. The sample is, of course, first excited so that it will not be in thermal equilibrium. In the ammonia beam maser this is accomplished by sending the beam through an electrostatic focusser which separates the excited from the ground state molecules by inducing dipoles in the molecules because of the Stark effect. The molecules emit their energy into the cavity causing the field to build up and induce more emission. The maser is thus a regenerative amplifier

and oscillates when the total power emitted equals the losses. It is the most coherent generator ever developed with a spectral purity of a part in 10^{12} or so. With a stable cavity design the maser serves as a frequency and time standard.

Third, a maser cavity technique using a gas is under development at Princeton University. This uses rubidium vapor at a very low pressure so as to greatly reduce collision broadening. Doppler broadening is reduced by filling the cavity with argon at about 1 mm pressure ; the argon serves as a buffer gas to, so to speak, make the rubidium atoms « stand still ». The collisions with the buffer gas result in very little broadening because of the nature and weakness of the interactions between argon – a noble gas — and rubidium in which the magnetic dipole hfs transitions are used. Thermal equilibrium is destroyed by optically « pumping » the rubidium by irradiating with rubidium resonance radiation.

Additional progress has been made with electronic stabilization and control methods, particularly the phase locking technique at M. I. T. Also solid state masers using spin resonance systems have been successfully developed as amplifiers and oscillators of extremely low noise. These open up a whole new field of application — atomic amplifiers — and might play a role in frequency and time standards either as very coherent generators or as low noise amplifiers of beam type masers.

To sum up, significant progress has been made towards the goal of practical atomic standards as well as a possible new international, primary standard. Most of the details must be left for the references.

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2. — Impedance Measurements

Contributions to the field of impedance measurements during the three year period from January 1, 1954 to January 1, 1957 have followed several lines. Considerable work has been done on the problems of analyzing errors and defects in present systems

and the means of eliminating them. Automatic impedance meters for use over wide frequency ranges have been investigated. A new type of standing-wave indicator has been developed for use in waveguides and coaxial lines. Special measurements problems brought about by the increased use of transistors and helices in antennas or traveling wave tubes have been attacked.

A calibration procedure has been devised which provides means of compensating for changes in wavelength and impedance introduced by the slot in slotted sections. Correction of results for the above errors can be accomplished in many cases of practical importance (1).

Means of evaluating figures of merit for probes in standing wave detectors have been investigated. The results of this work can be used to predict maximum error in a measuring system and to provide design criteria for minimizing such errors (2).

An analysis has been made of hybrid junctions as microwave impedance comparators. The degree to which imperfections in the junction affect the accuracy of the results have been defined (3).

New designs of mutual inductance standards have been achieved which permit greater theoretical accuracy in inductance computation and attendant improvement in calibration accuracy (4).

Automatic impedance meters have been designed which permit measurement of impedance over wide frequency ranges and the display of results on an appropriate impedance chart. The devices described operate in the microwave frequency range and employ swept oscillators, reflèctometers, and cathode ray oscilloscope or recorder display (5, 6).

Accuracies of 2 % in reflection coefficient and 2 degrees in phase have been obtained over a 12 % bandwidth. One version of this device is useful in the 300 kc/s — 30 Mc/s range (7).

Another method of rapid impedance measurement has been devised for the 30 kc/s - 5 Mc/s frequency range. Impedance is measured by the heterodyne principle. Local oscillator voltage for a mixer is derived from the current to the impedance and the voltage across the impedance is used as the signal voltage. The well known linearity of such a mixer provides a voltage output which is proportional to the impedance (8).

New types of standing wave indicators have been developed. One of these utilizes a section of circular waveguide arranged

perpendicular to a rectangular waveguide and appropriately coupled to it. TE_{10} waves in the rectangular guide excite TE_{11} waves in the circular guide with circular polarization whose sense depends upon the direction of propagation of the exciting wave. A standing wave is produced around the circular guide which duplicates that in the rectangular guide. A rotating probe measures standing waves in the same way that a traveling probe operates in a slotted line. Bandwidths of 20 % have been achieved (9). A similar device which operates over a much wider frequency range has been developed for use with coaxial lines.

Another interesting variation incorporates a helix in the standing wave detector which reduces wave velocity and extends the measurement range below 500 Mc/s (10).

A high precision method of measuring standing waves has been devised using a stationary detector and a sliding load (11).

Special measurements problems have been attacked in a number of ways.

The high frequency impedance of resistors in the range 2 — 400 Mc/s has been determined by connecting the resistor across a resonant cavity (12).

For use in the measurement of helical lines an analysis has been made of junctions between coaxial lines and helices. The results permit measurement of the helix impedance in the coaxial line (13).

A considerable number of instruments for the measurement of transistor parameters have been devised (14).

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3. — Noise Measurements

(*a*) *General.* — During the past three years, the scope of noise measurements was considerably expanded by a variety of techniques and analyses. A description of particular contributions will follow under a separate heading.

Important additions to the literature included a new book on noise in electronic circuits, with stress on low or medium frequencies (1). The nomenclature and measurement methods used conform with recommendations of the Institute of Radio Engineers (2). Physical phenomena relating to noise and mathematical techniques for the quantitative evaluation of noise were extensively treated in a group of tutorial papers (3, 4, 5, 6). The theory of two ports was extended to include noise effects (7). An equivalent circuit is derived consisting of a noiseless two port in cascade with a noisy two port. Experimental methods of evaluating the elements of the latter are also described.

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(*b*) *Measurement Techniques.* — Notable progress was reported in numerous articles. One paper discussed ways of utilizing sky noise in the 18 Mc/s to 300 Mc/s region to calibrate antennas and to evaluate receiver sensitivities for basic research in astronomy (1). Another described a special noise generator which can be used with electronic analog computers as the basic source of noise and other random quantities (2). Reports were presented on new instruments (3, 6).

Advances were made in the measurement of noise in magnetrons (4). An arc-discharge noise generator which acts as a rapid switch in a relaxation oscillator was constructed (5). It is capable of producing substantial noise power over the frequency range from 10 Mc/s to 1000 Mc/s and is useful for testing VHF and UHF receiving equipment. The Dieke method of measuring noise radiation was compared to a two-receiver method (7). The latter has been claimed to be more sensitive. A method for obtaining the best absolute accuracy in noise factor measurements was discussed (8). An experimental verification was reported on the theory of Rice for non-linear detectors in calculating noise level in radar receivers in which the second detector is a tube diode (9).

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4. — R-F Calorimetric Power Measurements

The calorimetric measurement of rf power has recently been extended to medium and low power levels. The most sensitive instruments reported use a dry load as power absorbing element and feature broadband operation. Flow systems with either direct or indirect heating of the calorimetric fluid by the rf power have been devised for medium power levels. In addition, work is reported on the use of adiabatic calorimeters, for the measurement of high rf power levels.

The Naval Research Laboratory (1) (Washington, D. C.) has developed an adiabatic (dry type) calorimeter having a sensitivity of several microwatts for use at K-band (24 000 Mc/s) frequencies. A servo-loop arrangement maintains essentially zero temperature difference between the matched rf termination and a surrounding evacuated metallic box, thereby preventing the loss of heat from the load. Power absorbed by the load causes the temperature of load and surrounding enclosure to rise at the same rate. Power is determined by a measurement of the temperature rise in a given time interval. Calibration is by means of the power.

The National Bureau of Standards (Washington, D. C. (2) has developed a microwave milliwatt calorimeter of better than one percent accuracy for use as a calibration standard for bolometers mounts at X-band frequencies. The calorimeter is described as

an « electrically (*dc*) calibrated aneroid micro-calorimeter of the Joule twin type » and uses a tunable thin-walled waveguide bolometer mount assembly as termination. The temperature rise of the assembly with respect to an identically constructed « dummy» mount is measured by means of a thermopile and precision potentiometer. To minimize the effect of ambient temperature variations the twin mounts are enclosed in a massive brass jacked immersed in an oil bath and the measurements performed in a temperature controlled room. The time constant is of the order of 5 minutes and the thermopile output about 12 microvolts per milliwatt. This calorimeter has recently been improved (3).

Variants of the above type of calorimeter have been built at the Bell Telephone Laboratories (5), at the Polytechnic Institute of Brooklyn (6, 7, 8) and by others (9). Commercial versions are also being produced. The Bell Laboratories calorimeters were designed for millimeter wavelengths and use conically-tapered lossy ceramic twin terminations in cylindrical waveguide. The Polytechnic Institute of Brooklyn has developed a set of broadband portable calorimeters for power measurements from essentially *d-c* to 75 000 Mc/s in the range from 0-1000 mW. In addition to rectangular waveguide units there is a coaxial calorimeter which covers the *dc* to 10 000 Mc/s range. The sensitivity (from 1 to 10 microwatts depending on the waveguide size) is mainly limited by temperature drift. The overall accuracies are from 2 to 3 percent at one milliwatt if precision *dc* measurements are used in the calibration.

A twin calorimeter which uses a differential air-thermometer (10) as temperature difference indicator has been described for use at X-band frequencies. An accuracy of 2 percent at 10 milliwatts is claimed.

The National Bureau of Standards is developing a coaxial conduction-calorimeter using a thin film disc type load for frequencies up to 1000 Mc/s (4). The power range is from 5 mW to 15 W and the accuracy better than 1 percent at 50 mW. A flow-calorimeter (4) is also being constructed in coaxial line using a film load in conjunction with a tractorially tapered outer conductor.

An X-band waveguide flow-calorimeter having a claimed accuracy of 1 percent (after appropriate correction) at a power level of 100 mW has been reported (11) which uses tapwater

flowing through inclined polystyrene tubes as the rf load. The heating effect of the rf power is balanced against that of known *d-c* power dissipated in another portion of the flow stream. Equality of the two powers is indicated by a sensitive thermistor bridge. The minimum detectable power is about 0.1 mW and is limited by temperature drift. A commercial coaxial self-balancing direct-reading flow-calorimeter providing full-scale readings of from 10 mW to 10 W with a claimed accuracy of 5 percent of full-scale has recently come on the market.

The National Bureau of Standards is continuing work on a high-power stirred water adiabatic waveguide calorimeter originally reported at the U.R.S.I.-I.R.E. Washington Meeting of May, 1954 by A. C. MacPherson.

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5. — INTERFERENCE MEASUREMENTS

In the U. S. A. during the last few years, there has been a great increase in the standardization and application of new techniques to measure the interfering radiations from receivers, transmitters and other devices. These techniques are aimed primarily at the reduction of the interference possibilities of equipement at the time of manufacture rather than after the equipement is widely dispersed in the field.

A considerable number of commercial facilities for both open field measurements and line radiation measurements are in regular use in the United States, especially for the measurement of the potential interfering emissions from broadcast TV and FM receivers. The methods in general use in the United States differ considerably from the present IEC proposal. Similar facilities are in use for the measurement of oscillator radiation and other emissions from other types of receivers.

In addition, there are a number of manufacturers and others equipped for the measurement of harmonic and other spurious emissions from transmitters. Certain standards are now under consideration by RETMA Committees.

* * *

Although the above techniques are generally adequate with regard to continuous wave emissions, standardization is not in a satisfactory state where the spurious emission is not of continuous wave, or of the same type as the wanted emission. A C.C.I.R. Study Group has given some consideration to this problem and ASA Committee C-63 has also studied certain of the instrumentation problems for particular purposes. There remains, however, a more general problem of overall standardization of parameters to be measured and it is believed that U.R.S.I. may be interested in the provision of a group of standards, a particular one of which may be used by other groups for their immediate purpose rather than having the diverse groups arrive at a multiplicity of standards, many of which are similar but not identical.

The standards would look toward the following sort of parameters :

1. A discrete set of band-widths in which the power or other parameter would be measured.
2. A discrete set of periods over which any integration would be made.
3. A discrete set of standard parameters, such as peak value, several quasi-peak values, average of voltage value, average of power value, or other value.
4. A discrete set of standards for the values to be assigned to measurement of phenomenon having very intermittent occurrence.

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6. — Field Strength Measurements

I. *Introduction.* — The major advances in field-measuring techniques in the U. S. A. during the period 1954-1957 lie in the areas of microwave near-field measurements, other specialized microwave field measurements, measurements at millimeter wavelengths, and measurements of radar echo area.

II. *Microwave Near-Field Measurements.* — Various techniques for measuring the near fields of a microwave antenna system and the near-field distortion produced by dielectric and conducting obstructions have been investigated (1, 2). Direct probing methods include the use of a small horn, a small open ended waveguide loaded with dielectric (3), and a short dipole (4).

As an alternative, a short, thin, linear conducting scatterer (5) eliminates errors due to the feed cable and supporting structure

associated with direct-probing methods and provides an accurate method of studying the field distribution inside a waveguide, inside a dielectric medium, or in the very near field of an antenna. On the other hand the conducting scatterer method requires well-designed power supplies, modulators, and signal sources with sufficient signal purity to permit an isolation of about 100 db (6) in a hybrid junction.

Many of these problems are greatly alleviated by the use of a linear scatterer whose scattered energy is modulated at an audio rate to help separate it from the unmodulated incident energy (7).

Many investigators have sought practical, accurate methods of determining the far field from near field measurements (8, 9).

III. *Specialized Microwave Field Measurements.* — Various types of equipment have been developed for specialized microwave field measurements. Among these are automatic phase plotters for various applications and frequencies (10, 11, 12). In many cases equivalent information about the fields may be determined with less complex equipment by measurement of the time- quadrature components (13).

Variations in synchronous detection methods have been employed to obtain increased receiver sensitivity (14, 15, 16). Current extensions of this work permit measurement of power levels 160 db below one watt at 25 000 Mc/s.

More refined antenna pattern-measuring equipment and automatic equipment for precision measurement of angular errors in directional antenna systems of the null-seeking type are now commercially available.

Many investigators have been studying the problems of determining the electrical properties of materials at elevated temperatures and frequencies (17, 18, 19). The use of surface waves on a large dielectric slab is an interesting innovation.

Specialized field measurements have frequently been made in connection with wave propagation studies (20). It is presumed that these will be reported by other commissions.

Studies of wave propagation in anisotropic media such as ferrites (21) have required the development of special techniques for such field measurements.

Field configurations in resonant cavities (22) and multimode waveguides (23) have been measured.

IV. *Measurements at Millimeter Wavelengths.* — There has been a growing interest in measurements at millimeter wavelengths (24). Millimeter investigations have included studies of signal sources and receivers (25, 26). Optical methods of measuring the properties of materials (27) and the wavelength (28) at these frequencies have been explored. Other field measurements have been made to determine atmospheric attenuation (29).

V. *Measurement of Radar Echo Area (Scattering Cross Section).* — Field measurements are frequently made to determine the scattering properties of many kinds of scattering targets. These include land (30), sea (30), aircraft, ships, aurora, meteors, and others (31).

Measuring techniques (32) include a continuous-wave system for measuring the echo of small models (33, 34), a pulsed radar for measuring full scale targets under dynamic conditions, and a parallel-plate transmission line method (35). In addition to the determination of scattering cross-section of more conventional targets, such systems have been used for studying the scattering and absorption apertures of antennas (36). Measurements also include the case of angula scattering where the receiving and transmitting antennas do not coincide.

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7. — MEASUREMENT OF THE POWER OUTPUT OF PULSE NOISE GENERATORS

In connection with the work done at Purdue University on pulse noise generators which covers the frequency range from audio frequencies to 100 000 megacycles, a considerable amount of time has been devoted to measuring techniques. The work in the last three years has been supported by the Rome Air Development Center, Griffiss Air Force Base, Rome, N.-Y. under contracts U. S. A. F. Numbers W28-099-ac-222, AF-30(602)-402 and AF-30(602)-1405.

Since the last International Meeting of U.R.S.I., we have made further developments along two lines :

1. Measuring the power output of low power pulse noise generators for calibration purposes particularly at 10 000 megacycles.
2. Determining the power output of high power, high repetition rate pulse generators where the average power is great enough to be measured directly by means of a power meter after the signal has passed through a single tuned band pass filter.

Under 1, above, a system has been developed, and equipment built for making measurements in the 3 cm band, in which the amplitude of the frequency components of a pulse generator can be determined by comparison of the *average power per pulse* with the known level from a standard random noise source passed through the same frequency selective system and amplifiers.

This method of measurement is described in detail in Section I of the Purdue Research Foundation Report entitled « Measurement of the Power Output of Pulse Noise Generators » dated April 30, 1956. Equipment for use in the 3 cm band is described in Section II of the same report.

Concerning 2 above, the theory and methods of measurement are described in Section III of the above report. Since the output of high power pulse noise generators is rated in terms of the rms power at the peak of the envelope of a wave train obtained by passing the signal through an ideal filter having a bandpass of one megacycle, and expressing this value in terms of db above the theoretical noise power kTB_n.

where :

k = Boltzman's constant, 1.38×10^{-23} joule per degree K.

T = temperature in degrees Kelvin.

B_n = noise bandwidth in cycles per second.

$W = kTB = 4.00 \times 10^{-15}$ Watt at a temperature of 290° K and a bandwidth of 10^6 cycles.

Our principal contribution has been the derivation by Dr. Hunt of the mathematical equation which expresses the relation between the so called peak power per megacycle of bandwidth and the average power at a known pulse repetition rate. The important

forms of this equation appear as equations (29), (31) and (35) of the above report.

The peak power per megacycle of bandwidth in db above kTB is expressed by equation 35 of the report, and is as follows ;

$$db_l = 10 \log_{10} (2 \times 10^{27} P_a G_p/B_n f_r)$$

where :

P_a = average power in watts.

G_p = power loss in the system and consists of the insertion loss of the filter at its midband frequency, plus any attenuation introduced to get the reading on scale of the power meter.

B_n = noise bandwidth (equivalent) of the filter in cycles per sec.

f_r = pulse repetition frequency in pulses per second.

The actual measurement of average power is made after the signal has passed through the filter whose bandwidth has been determined.

Report on Commission I Activities

submitted at the Plenary Opening Session

by Mr. B. DECAUX, *Chairman*

(*Translation*)

« To promote the setting up of common methods of measurement as well as the intercomparison and standardization of the measuring instruments used in scientific work » is according to article 1 of the statutes one of the aims of U.R.S.I., it is also the particular aim of Commission I.

The works carried out in this field during the recent years are dealt with in reports from twelve National Committees together with official documents from the International Consultative Committee on Radiocommunications (C.C.I.R.) and from the International Committee on Weights and Measurements, and several other papers.

Atomic standards are spreading and improve themselves. At the present time, various equipments are regularly operating ; they can even be found on the market. This is a topic where the fields of Commission I and Commission VII overlap, and the session devoted to Masers by Prof. Woonton will be of great interest to our commission. The use of frequency atomic standards become sufficiently reliable and now arises the question whether a new definition of the unit of time has to be based on such standards. This problem is investigated by a Consultative Committee of the International Committee on Weights and Measurements. This Committee has been asking officially Commission I of U.R.S.I. to organize the intercomparison of the various atomic standards in use, or of those which will incessantly be in use.

Previously the international frequency intercomparison had been organized by Commission I. Its revival shall be one of the major

items of our agenda, first for atomic standards, and also because new experiments have shown that kilometre and myriametre wavelengths are able to provide a far better accuracy than decametre wavelengths.

On this topic, Commission I shall provide a new contribution to C.C.I.R. which, at the Warsaw meeting, put under study new topics concerned with transmissions of frequency standards and time signals : use of very long or very short waves, decrease of accuracy due to propagation, mutual interferences between various stations.

The experiments decided in The Hagen on the suggestion of Prof. Boella, chairman of Sub-Commission III*b* on the study of the variations of propagation time of time signals, led to the setting up of very accurate techniques to measure the time signals ; such techniques are very useful for current measurements and particularly for the World-Wide Longitude Operation which is carried out along the I.G.Y. programme.

Several U.R.S.I. General Assemblies had recommended without any appreciable results an international intercomparison of power measurements ; we shall have to consider how such intercomparison might be undertaken.

Field strength measurements are becoming more important with the development of new modes of propagation of the shortest wavelengths. Progress in this field are very noticeable. Measurements have been made with rockets even inside the ionosphere. On the other hand, radio-astronomers are interested in the calibration of their receivers in order to deduce the energy density of extra-terrestrial radiations.

Some physical measurements are using methods set up at first for radio aims. We will have to consider for example whether the velocity of light lead to a change in the median value adopted in Sydney and confirmed at The Hagen or if we can keep this value. The techniques set up for nuclear resonances and radiospectroscopy were also useful to the measurement of magnetic quantities.

Besides the opening and closing sessions, five sessions are organized for Commission I as stated in the programme. For each topic, general review by a well known specialized scientists whom I want to thank, will preceed the discussions.

The sessions will be as follows :

1. Frequency standards, and particularly atomic standards, review by Dr. L. ESSEN.
2. Transmissions of frequency standards and time signals, review by Mr. W. D. GEORGE.
3. Power measurements, review by Dr. SAXTON ; Field strength measurements, review by Mr. R. S. KIRBY.
4. Continuation of 1st and 2nd sessions.
5. Physical measurements using radio techniques, review by Prof. P. GRIVET.

Minutes of the Meetings

Meeting of Official Members : Friday, August 23, 1957, 2.30 p. m.

Chairman : B. DECAUX

The Chairman opened the session by conveying his good wishes to the members present.

1. — *Organization of Technical Sessions.*

The Chairman put forward his suggestions for the organization of the five technical sessions. After discussion, the programme adopted was as follows :

Name	Date	Time	Subject	To be introduced by
A	28-8	14.00	Frequency standards ; particularly atomic standards	Dr. ESSEN
B	29-8	14.00	Standard-frequency transmissions and time signals	W. D. GEORGE
C	30-8	9.30	Power measurements and Field Strength Measurements	Dr. SAXTON R. S. KIRBY
D	2-9	14.00	Continuation of A and B	
E	3-9	9.30	Physical Measurements by radioelectric techniques	Prof. GRIVET

The opening technical session would take place on August 26 at 14.00.

There would be a further closing technical session on September 4 at 9.30. On September 3, during the afternoon, Commission VII

is holding a session on the Maser, which would be of interest to members of Commission I.

2. — *Documents.*

The Chairman drew attention to the documents which had been received. In addition to National Reports, there was a certain number of individual contributions.

3. — *Resolutions.*

Resolutions would be considered during the course of the technical sessions and would be reviewed collectively during the closing session.

4. — *Administrative Questions.*

The Chairman asked members to give thought to the following questions :

(*a*) The creation of sub-commissions — a brief exchange of views did not reveal the need for any such sub-commissions of Commission I.

(*b*) The organization of colloquia in the interval between General Assemblies.

(*c*) The nomination of officers.

The session ended at 3.30 p. m.

First Meeting : Monday, August 26, 1957, 2.00 p. m.

Chairman : B. Decaux.

In opening the meeting the Chairman extended good wishes to the members present. He also referred with regret to the death of Dr. Vecchiachi, which had occurred since the last General Assembly.

Mr. Weber undertook the duties of reporter in the English language.

1. — *Organization of Technical Sessions.*

The Chairman gave details of the programme of five technical sessions, which had been compiled at the meeting of official members of Commission I on August 23. This programme was adopted by the Commission.

2. — *Documents.*

12 National Reports had been presented to the Assembly and had been distributed. A certain number of personal contributions had also been received.

3. — *Liaison with other International Organizations.*

The Chairman stated that certain questions dealt with by Commission I were also of interest to other international organizations (C.C.I.R., International Committee of Weights and Measures). The answers to these questions should give rise to resolutions. Commission I should formulate other resolutions (e. g. concerning measurement of power, velocity of light, etc).. In the discussions it was essential not to lose sight of international interest and the possibility of international collaboration.

4. — *Technical Questions.*

The Chairman went on to examine certain technical aspects of the questions which were to be discussed at future sessions.

For example, in connection with frequency standards, it was necessary to consider.

(*a*) Principles, construction and precision of parts of apparatus ;

(*b*) Their use and their comparison with each other and with astronomical standards. The Committee of Weights and Measures had asked Commission I to organize such comparisons. They could therefore form a programme of work and the subject of a resolution.

As another example, the question of standard frequency transmissions should include :

(*a*) The examination of general problems.

(*b*) The replies to be made to questions posed by C.C.I.R.

Consideration should also be given to the interference between different standard frequency transmissions — a problem which had already formed the subject of a recommendation to the last General Assembly.

An exchange of views took place on the question of the comparison of standard frequencies (use of submarine cables, interchange of standards, etc.).

The Chairman pointed out that the classification of frequency bands recommended by C.C.I.R. is not used by U.R.S.I. He asked whether a recommendation on this subject was necessary. After discussion, Commission I came to the conclusion that it was desirable to use a numerical nomenclature for frequency bands, but there was divergence of opinion about the limits of the bands. The Chairman was asked to make contact with the Chairman of other commissions, so that general agreement on this subject might be obtained.

An exchange of views took place on the name of the unit of frequency (c/s, hertz). It was decided that Commission I ought to take an interest in this question, but that a resolution could not be envisaged before the next General Assembly.

Finally, Mr. Kirby drew attention to certain difficulties in connection with the specification of field intensity. It was agreed to examine this question during Technical Session C.

The meeting ended at 3.45 p. m.

Second Meeting : Wednesday, August 28, 1957, 2 p. m.

Chairman : Mr. DECAUX.

The meeting was devoted to a consideration of Frequency Standards, and a review of recent work on this subject was presented by Dr. ESSEN. An account was given of the improvements in quartz standards which can be obtained by operating them at the temperature of liquid helium ; of the future possibilities of Masers as frequency standards ; and of the Caesium clock and the results obtained with such clocks in Great Britain and the U. S. A.

During the subsequent discussion, attention was drawn to the importance of securing special purity in the exciting oscillator of a caesium clock and of the difficulty of avoiding frequency modulation when the exciting voltage is derived by multiplication of a much lower frequency. Variations of the power of the exciting oscillator over a wide range did not alter the observed resonant frequency of the N. P. L. caesium standard by more than 1 part in 10^{10}. Shifts greater than this have been observed with other caesium standards, but they can probably be ascribed to effects in ancilliary apparatus.

The caesium standard has revealed both periodic and irregular variations in the rate of rotation of the earth during the past two years.

Preliminary results obtained with the Ammonia Maser in the U. S. A. and the U. S. S. R. were reported. The frequency obtained with such devices depends on a number of factors and the present stability is about 1 part in 10^9.

Preliminary consideration was given to a resolution brought forward by Dr. ESSEN.

Third Meeting : Thursday, August 29, 1957, 2 p. m.

Chairman : Mr. DECAUX.

Mr. W. D. GEORGE surveyed the present position on standard frequency transmissions and outlined the problems to be tackled to obtain an adequate world service. The subsequent discussion was devoted mainly to the problems of interference (both by one S. F. T. with another and by other stations, operating on or very near the same frequencies, with S. F. T.'s) and to a consideration of the most effective form of pulse to be used in time signals.

Mr. GEORGE called attention to the SITEC 100 kc/s pulse navigational system (described in an I. R. E. specialist report). The range was stated to be 1500-2000 miles and the precision 0.1 μs. He also called attention to the system on the Neuchatel transmission, in which the signal consisted of five square-wave pulses of 1 μs duration.

Dr. ESSEN raised the question of the relative importance of the pulses and the tone, and the possibility of extending the pulses and the expense of the tone. The general feeling was that the tone was relatively unimportant, but Mr GEORGE thought that there were a good many users of WWV who would not welcome any change.

The question of the phasing of the time pulses was discussed and Prof. KOGA put forward the suggestion that, since the frequency was more important for local use and the time signals for distant use, the phasing of the signals should be such as to give the greatest convenience to distant users.

Preliminary consideration was given to two resolutions suggested by Mr. GEORGE and one by Dr. ESSEN.

Fourth Meeting : Friday, August 30, 1957, 9.30 a. m.

Chairman : Mr. W. D. GEORGE,then Mr. DECAUX.

A discussion on Power Measurements was opened by Dr. SAXTON, who gave an account of the very considerable developments that

had taken place during the past three years. He also pointed out that improved techniques were still required at frequencies above 30 000 Mc/s and below 3000 Mc/s.

Instruments in which changes of temperature or resistance of an absorbing load were measured had been developed for powers from 1 W to 100 W and had accuracies estimated at from 1 % — 3 %, although there might be systematic errors, particularly at the higher frequencies and lower powers. International comparison would be valuable for checking such errors. It was estimated that thermistors and bolometers had errors of as much as 30 % at frequencies of about 50 000 Mc/s, but they were still useful if calibrated.

The torque-vane type of wattmeter gave an accuracy of about 3 % for powers between 2 and 10 watts and instruments in which the vane was situated in a cavity were accurate to about 2 % in the power range from 5 - 30 mW, at frequencies of about 10 000 Mc/s. Similar results were obtained at 60 000 Mc/s.

The electron-beam technique could be used for powers of about 50 mW, and its accuracy was being investigated.

After this introductory talk, the Chairman drew attention to the resolution at the last General Assembly on international comparison of power-measuring equipement. Dr. SMITH-ROSE reported that, although the United Kingdom was ready to take part in such comparisons, the only action so far had come from Prof. KOGA, who had offered to prepare and send an instrument suitable for comparison with the N. P. L. equipment. Prof. KOGA reported that he had brought the instrument and arrangements were made to use it in England and then in the United States. It was pointed out that international comparison had been suggested more than six years ago ; since nothing had been done, the Commission might wish to drop the programme. The U. S. A., UK and Japanese delegates thought the programme should remain and said they were prepared to put it into effect in the near future. The Canadian and French delegates expressed interest, although they were not in a position to participate.

Dr. SMITH-ROSE thought that some countries might be holding back in order to perfect their equipment. He felt they should not do this since it was important to establish the degree of accuracy of apparatus at present in use. This was highly desirable in con-

nection with measurements such as field strength, which were of interest to other Commissions.

Prof. BARLOW then gave an account of methods depending on the Hall effect and on the pressure of radiation, describing the precautions to be taken and the fields of application of such methods. At present, the Hall-effect instruments gave only relative values but there was a possibility that they might be developed to give absolute values.

Dr. ENGEN gave an account of the micro-calorimeter being developed at the N.B.S. The temperature rise was only 0.05° C and precautions were therefore necessary. It might be the most accurate instrument in the present state of the art and an accuracy of better than 1 % might be possible.

In opening the discussion on field-strength measurements, Dr. R. S. KIRBY indicated the fundamental difficulties of relating the quantity actually measured to the field strength, and of not disturbing the field by the use of the measuring instrument. He referred also to the need for a uniform nomenclature and mentioned the recommendation of the I. R. E. In this, electric-field strength is defined as the magnitude of the electric-field vector at a given place, resulting from the passage of a radio wave. The use of the term « electric intensity » was deprecated.

Prof. BARLOW gave an account of methods using a rotating dipole and explained their advantages in exploring the field in waveguid structures.

Mr. SELBY raised the general question of the relatively small effort devoted to work on standardization. He thought that it was important to draw up a list of priorities in such work and to state clearly the quantities, ranges and accuracies required. Although in general sympathy, Dr. SMITH-ROSE thought the position was not quite as bad as Mr. SELBY had suggested. Much had been done in the field of standardization and it might be unwise to attempt too ambitious a programme. Experience with power measurements had not been encouraging.

Mr. CHAPIN outlined the problems of noise measurement and stressed the need of greater uniformity in the methods adopted.

Fifth Meeting : Monday, September 2, 1957, 2.00 p. m.

Chairman : B. DECAUX.

The Chairman, requested Dr. Louis ESSEN to present a resolution concerning the further development and intercomparison of atomic frequency standards. In the discussion two basic methods of intercomparison were outlined, the direct method which requires radio signal transmissions between the places of comparison or transport of the standard ; the indirect method which refers to the local observatory time standard. It was agreed to refrain from specification of frequencies in view of the small numbers of standards actually available at this time for intercomparison. The resolution, together with additional comments concerning factors important in the intercomparison of atomic frequency standards, were unanimously approved.

The Chairman then called upon Mr. W. D. GEORGE to discuss a resolution concerning the transmission of standard frequencies and time signals as a world-wide service. The resolution was unanimously adopted with slight clarifying additions. Mr. GEORGE also presented a resolution concerning the scope of standardization programs in the high-frequency and microwave regions of the spectrum. The resolution was unanimously adopted.

Finally, Mr. W. D. GEORGE, upon request by President Decaux, called upon Mr. M. THOMPSON of the National Bureau of Standards, U. S. A., to present briefly a system of frequency stabilization for microwave oscillators which had been found particularly useful for frequency measurements and intercomparison. The system, thought to be novel, can achieve stability of the order of one part in 10^9 with relatively simple means.

Sixth Meeting : Tuesday, Sept. 3, 1957

Chairman : W. D. GEORGE, then B. DECAUX.

Physical Measurements based on Radio Techniques.

Prof. P. GRIVET presented a progress report on recent measurements of the velocity of light. New methods were developed by using the Shoran system of navigation in the United States and the OBOE system in England ; a modification was developed by Mr. Florman in the United States, based on phase measurements

at 115 Mc/sec. The major error in such long-distance-transmission methods resides in the uncertainty of the refractive index of air and its probable lack of uniformity. An entirely different method by Rank and Plylor (United States) uses infrared transmission, determining the frequency by means of magnetic resonance, involving quantum theoretical relations.

Improvements in the classical methods of measurement have also been made, by Dr. L. Essen using the resonator principle with empirical corrections for the skin effect ; by Mr. Froome employing spherical waves in a constant-phase wave-guide interferometer of very considerable accuracy ; and by Bergstrand using the optical method, modulating the light beam by means of a Kerr cell at 9 Mc/s and utilizing the « Halbschatten » comparison method.

It was stated that a value of the velocity of light could now be specified as 299 792.5 $\pm$ 0.4 km/s A pertinent resolution was discussed and will be formulated by a small group.

The Chairman then called upon Dr. M. I. Zhabotinski to present a resumé of his paper « Frequency (Phase) Multipliers for Measuring Devices ». The cascade chain can be so designed that the overall drift in 10 min. does not exceed 4×10^5 radians. Dr. Essen referred to work in England and proposed comparison of the two methods.

Prof. R. H. George of United States presented a summary of his work on standard signal sources for impulse noise and referred to additional work in commercial organizations. For the calibration of the power output, better standards for microwave power measurements will be necessary.

Mr. M. C. Selby called attention to the document 96 « Correlation Theory of Electric Fluctuations and Thermal Radiation », submitted by Dr. Rytov having bearing on standards for noise measurements.

Prof. P. Grivet then resumed by giving an exposition of measurements of the magnetic field quantity B by means of paramagnetic-resonance phenomena, either utilizing the nuclear resonance effect discovered by Purcell and Bloch in 1948 or the electronic resonance effect discovered by Zavoisky in 1945. He mentioned also the ferromagnetic resonance discovered by Griffith in 1946 which apparently had not been given adequate attention.

Finally, Dr. J. M. RICHARDSON gave a progress report on the use of an oxygen line for an atomic clock, deducing theoretically from first measurements of the line width a possible final accuracy. Dr. ZHABOTINSKI mentioned similar efforts by SHIMODA.

Seventh Meeting : Wednesday, September 4, 1957, 9.30 a. m.

Chairman : B. DECAUX, then M. D. GEORGE.

Dr. ESSEN proposed a resolution, re-confirming and strengthening a similar one passed at the XIth General Assembly, concerning the international intercomparison of power measuring apparatus. The resolution was unanimously adopted.

Mr. DECAUX distributed, for information, the final texts of the resolutions concerning international intercomparison of atomic frequency standards and transmission of standard frequency and time signals.

R. S. KIRBY presented a draft resolution concerning the concepts of Radio Field Strength and Radio Field Intensity. After discussion and amendment, this resolution was unanimously adopted.

Dr. DECAUX then called on Prof. KOGA to present a resumé of his results on the determination of the elastic constants of quartz, taking into account the piezo-electric polarization forces, which had previously been considered negligible.

At this point, Dr. DECAUX left to attend the Executive Committee and the Chair was taken by W. D. GEORGE.

The Chairman called on Dr. ESSEN to present the resolution, prepared in collaboration with Prof. GRIVET, recommending the use of a more recent value for the propagation of electromagnetic waves in vacuum. The resolution was unanimously adopted.

Mr. GEORGE described briefly a new liquid-helium container for the standard quartz clock at N. B. S.

The meeting ended with a hearty vote of thanks to its President, M. DECAUX.

Report on the Activity of Commission I during the General Assembly

submitted to the Plenary Closing Session

by B. DECAUX, *Chairman*

(*Translation*)

Commission I hold seven sessions which however, were too short for the importance of the topics dealt with. Some of them led to animated, and sometimes passionate discussions which lasted for several hours. Such discussions, as stated at the Opening Session, were prepared by general reviews ; their results are five resolutions which I am going to summarise.

The topic which initiated the most important discussion was obviously the frequency atomic standards, the development and futur of which are most prodigious. The International Committee on Weights and Measurements had asked U.R.S.I. Commission I to organize international inter-comparisons of such standards.

It seems rather premature to draft an accurate coherent program ; the subject is indeed most critical, and calls to the most fondamental principles of metrology. Nevertheless, a resolution was adopted which recommends two kinds of comparisons :

1) by means of transmissions of standard frequencies and time signals ;
2) by circulation of a standard between the various national laboratories.

The resolution stresses on some cares to be taken in order to obtain the best results. On the other hand contacts and agreements have been taken between responsibles of frequency standards in the world, which allows to expect a close collaboration in this field.

The discussion on transmissions of standard frequencies and time signals led to a resolution which is in fact the answer to

C.C.I.R. questions. This resolution emphasizes the importance of transmissions on low frequencies, of time signals as regards to audio modulations, and also the problem of their adjustment and the difficulties that may arise from a too great increase of the number of stations.

The resolution on power measurement is nearly the same as the resolutions taken at the previous General Assemblies. It emphasizes the importance of international intercomparisons of standards.

A resolution was also taken for field strength measurements which defines the quantities in order to avoid confusion, and makes a distinction between measurement of vectors and measurement of energy density.

This desire for clarity in the definition of quantities used in radio-technique led Commission I to adopt a recommendation which will be forwarded to the concerned international agencies in order to reach a standardization of the quantities and of the various fields of related measurements.

A last resolution takes the place of the resolution adopted in Sydney and in The Hagen on the velocity of light in vacuum. The progress made during these last years are such that we were able to add one more decimal to the previous figure, and to reduce by five the probable error. This value is hereforth :

$$299\ 792.5\ \text{km/s} \pm 0.4$$

Many other interesting topics were discussed but did not lead to formal resolutions.

I want to express my warmest thanks to all those who took part in our works and help us to make our sessions most successful. My gratitude goes to the authors of the reviews, and also to Mr. W. D. George who took several times the chair, and to the devoted Reporters, MM. Abadie and Weber.

Resolutions

Resolution n° 1

It is resolved that in view of the importance of atomic standards for frequency and time measurements it is recommended that their further development should be vigorously pursued and that their frequencies should be intercompared by means of radio transmissions and by the circulation of a single standard around a number of national laboratories.

Additional Comment : It should be noted that in making the proposed intercomparisons, the frequencies should be expressed either in terms of an atomic frequency such as that of the caesium F, m (4.0) $\leftarrow\rightarrow$ F, m (3.0) line at zero field or in terms of the unit of time scale UT2. In the latter case the time signals used should be stated so that the interval between these signals can be expressed in terms of the caesium resonance.

If the frequency varies with any parameters external to the atom, the precise values of these parameters should be stated.

Resolution n° 2

In order to establish the best means of securing a reliable worldwide service of standard frequency and time signals transmissions, it is recommended that attention be given to Resolution n° 179, Question n^{os} 140, 141, 142, and Study Programme n° 101 of the C.C.I.R. Plenary Assembly, 1956. In particular, the following questions should be studied :

1. The merits of frequencies below 100 kc/s for standard frequency transmissions and time signals.

2. Methods of recognizing without ambiguity the seconds pulses of different standard frequency transmitting stations including the case of reception at great distances.

The study should include the optimum type of time signal to be used and the advisability of synchronizing time signals from different stations.

3. The number and location of station required for world coverage. (Any further increase the number of stations operating in some geographical areas will result in a degradation of the service.)

4. The advisability of reducing the period of tone in favor of pulses.

Resolution n° 3

It is strongly recommended that the national laboratories should intercompare their standards of power measurement at frequencies in the neighborhood of 3000 Mc/s and 10 000 Mc/s. The comparisons to be coordinated by Dr. R. L. Smith-Rose, Director, Radio Research Station, Ditton Park, Slough, Bucks, England.

Resolution n° 4

In order to avoid confusion between the terms « radio field strength » and « radio field intensity », it is recommended that :

1. *Radio Field Strength* refers to the magnitude of the electric or magnetic field vector (E or H) at a given location resulting from the passage of radio waves.

2. *Radio Field Intensity* refers to the power density of electromagnetic waves passing through a surface normal to the direction of propagation.

Resolution n° 5

In order to stimulate international and national efforts in the standardization programs of high-frequency and microwave quantities such as power, impedance, voltage, current, attenuation, field strength, noise, etc., the XIIth Assembly of U.R.S.I. recommends to members of the U.R.S.I., the I.E.C., the C.C.I.R., I.S.O., and other international groups concerned with electrical standards hat the following be done :

(*a*) Compile, as soon as possible, a table of *rf* quantities including those distributed in time, frequency and space to be standardized. This table shall specify dynamic ranges, frequency ranges and corresponding desirable practical accuracies for primary standards. It shall also specify desirable priorities for the various quantities and corresponding ranges.

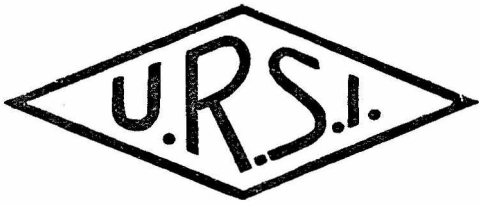
(*b*) Information and tabular material, as requested in (*a*) above, shall be forwarded to the Chairman of Commission I, U.R.S.I., for consolidation and possible adoption at the XIIIth U.R.S.I. General Assembly. It is desirable that this table be brought up to date at successive General Assemblies.

Resolution n° 6

In view of the progress made since the XIth General Assembly in the measurement of the velocity of electromagnetic waves, it is recommended that in radio engineering problems its value in vacuum be taken as :

$$299\,792.5 \pm 0.4 \text{ km/s}$$

INTERNATIONAL SCIENTIFIC RADIO UNION



Proceedings of the XIIth General Assembly

held in Boulder, Colorado, U. S. A.
from August 22nd to September 5th, 1957

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On Radio and Troposphere

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COMMISSION II

On Radio and Troposphere

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List of Reports and Papers submitted to the Commission

The asterisk indicates reports published in this part.

E = Original text in English.

F = Original text in French.

N°	Titles and Authors
1	C.C.I.R. Findings of interest to U.R.S.I., *U.R.S.I. Inf. Bull.*, **100**, 48-81 (E).
15	VHF propagation tests over mountain paths, I. MURAKAMI, Technical Research Laboratory, Japan Broadcasting Corporation (E).
16	Theory of tropospheric propagation near and beyond the radio horizon, O. TUKIZI, Electrical Communication Laboratory, Musasinosi, Tokyo (E).
17	Multi-path transmission through the troposphere, T. OMORI, The Electrotechnical Communication Laboratory, Nippon Telegraph and Telephon Corporation (E).
18	Ray Theorical analysis of fading due to duct, F. IKEGAMI, *Ibid.* (E).
19	Multiple diffraction of electro-magnetic waves by spherical mountains, F. FURUTSU, Radio Research Laboratories, Kokubunji, Tokyo (*Journ. Radio Res. Lab.*, Vol. 3, n° 14, Oct. 1956) (E).
20	On the relationship between scattering of radio waves and the statistical theory of turbulence, K. TAO, Radio Research Laboratories (E).
21	Characteristics of radio waves diffracted by a mountain, T. KOONO, Y. KURIHARA, M. FUKUSHIMA. *Ibid.* (E).
22	A new type refractive index variometer, K. HIRAO. *Ibid.* (E).
29	Wave propagation over irregular terrain, K. FURUTSU, Radio Research Laboratories, Kokubunji (E).

N°	Titles and Authors
54	Propagation of electro-magnetic waves over mixed paths, K. FURUTSU, Radio Research Laboratories, Kokubunji (E).
81	Quasi-Rayleigh fading in tropospheric propagation, Ing. P. BECKMANN (E).
84	Inhomogeneous path and general features of ground wave propagation, E. L. FEINBERG, P. N. LEBEDE, Physical Institute U.S.S.R. Academy of Science (E).
85	Fluctuations in a wave scattered by inhomogeneities whose velocities are stationary random-functions of the time, G. GORELIK, M. RODAK, A. FRANTZESSON (F).
86	Theory of wave propagation in the turbulent atmosphere (Review of work carried out in U.S.S.R.), V. A. KRASSILNIKOV, Faculty of Physics, Lomonosov State University, Moscow (E).
87	On the scattering theory of electromagnetic waves in the medium with random irregularities of the refractive index, V. A. KRASSILNIKOV, V. V. MERKULOV. *Ibid.* (E).
105	Comparison of Milington's method and the equivalent numerical distance method with theory, Z. GODZINSKI, Research Centre of the Institute of Telecommunications, Wrocaw, Poland (E).
111	Comparison of measured and computed refractive bending in the troposphere, L. J. ANDERSON, L. G. TROLESE, J. B. SMYTH, Smyth Research Associates, San Diego, Calif. (E).
112	Foreground terrain effects on overland microwave transmissions, L. G. TROLESE, *Ibid.* (E).
114*	Report on the work of C.C.I.R. Study Group V at the VIIIth Plenary Assembly in Warsaw, 1956, R. L. SMITH-ROSE, Chairman (E).
117	Some remarks about scattering-experiments in the 100 Mc/s-band, Dr. J. GROSSKOPF (E).
120	Some results of propagation tests at 1000 MHz and 4000 MHz on two optical paths of different lengths, F. CARASSA, B. PERONI (E).
123*	Report of the U. K. National Committee on Tropospheric Wave Propagation, Dr. R. L. SMITH-ROSE (E).
140*	Report of the Swiss National Committee, Dr. GERBER (E) (F).

N°	Titles and Authors
152	Some experimental investigations of long range VHF and UHF tropospheric propagation, J. A. SAXTON, G. W. LUSCOMBE, Radio Research Station, D.S.I.R., Slough, England (E).
153	Some features of VHF and UHF ground-wave propagation, J. A. SAXTON, B. N. HARDEN. *Ibid.* (E).
155*	Report on Radio Wave Propagation within the Horizon (E).
157*	Report of the New Zealand National Committee (E).
160*	Report of the Italian National Committee (E).
166*	Report of the Netherlands National Committee (E).
171*	Report of the Czechoslovakian National Committee (F).
174	The influence of moisture in the ground, temperature and terrain on ground wave propagation in the VHF-band, B. JOSEPHSON, A. BLOMQUIST, Research Institute of National Defence, Sweden (E).
175	Some microwave propagation experiences from a « just-below-horizon » path, B. JOSEPHSON, F. EKLUND. *Ibid.*(E).
176	Distance dependence, fading characteristics and pulse distortion of 3000 Mc/s trans-horizon signals, B. JOSEPHSON, G. CARLSON (E).
185*	Report of the Canadian National Committee (E).
191*	Report of the German National Committee (E).
198*	Report of the Japanese National Committee to Commission II, H. HATAKEYAMA, K. ISONO (E).
205*	Report of the Polish National Committee to Commission II (E).
210*	Report of the French National Committee to Commission II (F).
214*	Report of the Swedish National Committee to Commission II, M. FEHRM (E).
232	Some results of tropospheric scatter propagation measurements in Poland, S. MANCZARSKI, J. MOLSKI, L. KIERNOZYCKI (E).
243	Meteorological studies of refractive index distribution, K. H. JEHN, V. E. MOYER, J. R. GERHARDT, N. K. WAGNER (E).
244	Radiopropagation measurements at millimeter wavelengths, C. W. TOLBERT, A. W. STRAITON (E).
245	The role of stratospheric scattering in radio communications, H. G. BOOKER, W. E. GORDON (E).
246	On the total bending of radio waves, B. R. BEAN, B. A. CAHOON (E).

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247	On the prediction of VHF transmission loss, B. R. BEAN (E).
248	Dependence of VHF-UHF radiotransmission loss on angular distance, P. L. RICE (E).
249	Overwater scatter propagation in thunderstrom conditions, W. S. AMENT, F. C. MACDONALD, D. L. RINGWALT (E).
250	Meter wavelength propagation at great distance and heights beyond the radio horizon, L. A. AMES, E. J. MARTIN, T. F. ROGERS (E).
268	Observations of antenna beam distortion in trans-horizon propagation, Alan T. WATERMAN (E).
269	Some general relationships in trans-horizon propagation, same author (E).
270	Radio studies of atmospheric turbulences on line of sight paths, I. W. HERBSTREIT, M. C. THOMPSON Jr. (E).
296*	Report of the U. S. A. Commission II (E).
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Preface

A symposium on Tropospheric Wave Propagation within the Horizon was held at the United States Navy Electronics Laboratory, 30 March to 2 April 1953, under the chairmanship of Dr. Charles R. Burrows (138). The objective of this symposium was to summarize the known characteristics of optical fields with emphasis on those effects which had not been adequately explained by theory. Three topic seminars, followed by an informal discussion, covered : Terrain Effects, Refraction Effects, Combined and Other Effects.

At the request of Dr. Burrows, President of U.R.S.I. Commission II, a special report on tropospheric propagation within the horizon was prepared for the U.R.S.I. XIth General Assembly. The report contained the following sections :

1. Attenuation of Radio Waves in the Atmosphere.

2. Multipath Propagation.
3. Focusing-Defocusing Phenomena.
4. Irregular Terrain.
5. Recommended Investigation.
6. Bibliography.

The current report will be an attempt to summarize some of the major studies completed since September 1954.

1. — Introduction

Since the atmosphere is stratified, more or less, horizontally, most of the energy will follow the geometrical Fermat ray for grazing angles greater than one or two degrees. Focusing-defocusing, and diffraction will become important for transmission paths parallel to the stratification. A detailed discussion of the radio hole phenomenon associated with air-to-air transmissions will be found in the special report prepared for the XIth General Assembly. Recently tropospheric ray bending has received revived interest. For radiation transmitted at grazing angles greater than two or three degrees, it is expected that additional refraction-diffraction effects will be important only for specific applications.

The perturbation of an electromagnetic field by an irregular surface is beset by the same difficulties experienced in the study of the effect produced by an inhomogeneous medium. A major difficulty lies in the fact that no satisfactory description of the surface or medium has been evolved.

2. — Tropospheric refraction

(*a*) *Ray Bending*

Because of the improvements in radar techniques for measuring elevation angles of high altitude targets, considerable work has been done in recent years on the problem of tropospheric bending of electromagnetic waves.

A number of methods have been developed for computing bending from refractive index profiles of arbitrary shape, (22, 26, 113, 42). First order corrections have been computed assuming a standard atmosphere, and these corrections are a function

only of the angle of arrival at the earth and the surface refractive index.

One can make second order corrections to account for systematic departures of the atmosphere from standard. These corrections are a function of season and geographic location. Climatological studies have been made of such corrections at thirty-four geographic locations (43). Monthly means, as well as diurnal variations, were computed. These corrections represent about the best that can be done without detailed refractometer measurements at the time and place where corrections are needed.

Any climatological study must depend upon radiosonde data as its primary source of information. This causes errors because the humidity sensing element has a relatively slow response. Since humidity is an important term in the refraction index equation, the measured profiles are always less severe than the true ones. Fortunately, however, most of the variability and most of the bending takes place in the lowest 10 000 ft. of the atmosphere. In this region the flat earth approximation is valid, which depends only on the end values of refractive index (at the surface and 10 000 ft.) rather than the shape of the profile. The maximum errors from this cause are of the order of one milliradian.

Superimposed on the radiosonde error is the fact that at any time and place, the refractive index structure causing the bending will be somewhat different than it was at the time and place where the radiosonde data were taken. Fannin and Jehn's work on the day-to-day variations in the United States shows these errors to average about $\pm$ 2 milliradians in the winter and $\pm$3 milliradians in the summer at a grazing angle of 50 milliradians or about 3 degrees. Extremes run about a milliradian more.

Comparisons between the bending as calculated from radiosonde data and the bending measured using a sea-interferometer technique have been made over a range of profiles from standard to strong ducting (3). These comparisons were made at 400 and 1000 Mc, and show good qualitative agreement. The deviations were $\pm$ one milliradian. Since the radiosonde data were taken about 6 hours before and within 100 miles of the time and place where the bending occurred, this deviation is about what one would expect, using radiosonde data.

One can conclude that the present state of our knowledge of refractive bending allows one to correct for such errors in measuring elevation angle to ± 3 milliradians at low angles of arrival. Since the total bending decreases rapidly with increasing elevation angle, the corrections become quite small for elevation angles above 10^{o}.

It seems clear that the computed bending is in sufficiently close agreement with experiment that no gross effects have been overlooked. It would be comforting to have further experimental work comparing measured bending with detailed refractometer profiles taken at the same time and place.

(*b*) *Transmission through Inhomogeneous Media*

Several theoretical studies have been made of the effect of random refractive index variations on electromagnetic fields along the direction of propagation (67, 91, 95, 124, 134, 9). As is true with all diffraction problems, the two cases considered are refractive changes in distances large compared to the wavelength, and changes in distances small compared to the wavelength. In the former case ray theory is found to be adequate ; in the latter case the wave treatments are tractable when the scales of index changes are sufficiently small compared to the wavelength so that only a few terms in the field expansion are necessary.

Phase and amplitude variations have been measured on an optical link (51). The variance of phase was greater than expected from the measured inhomogeneities along the path. The phase variations were larger than the corresponding amplitude variations, which can be explained in terms of large scale variations in refractive index. Phase difference variations in 9350 Mc radio signals arriving at antennas separated by 500 feet were found to be in good agreement with the above observations on 1,046 Mc (32). Both experiments yielded small amplitude variations, indicating that the secondary field is not randomly phased with respect to the primary field. Others have investigated the stability of the phase and amplitude of radio signals (118, 105, 72).

Several studies have been made of the effect of atmospheric discontinuities on radio fields (9, 36, 37, 92).

3. — Irregular boundaries

(*a*) *Sea Surface*

A recent paper (64) has summarized the status of the knowledge of the mechanisms of radar sea clutter. Data is presented which is in agreement with the theoretical results derived on the assumption that reflections take place from small patches illuminated by direct and reflected radiation. At small depression angles the destructive interference gives rise to a so-called «critical angle» below which the scattering cross-section decreases rapidly. In calm seas horizontal polarization gives much less clutter than vertical polarization. For calm seas the scatter cross-section is proportional to the frequency to the fourth power. Measurements (135) of the back-scatter cross-section have been made over incident angles from 0 to 90° at frequencies between 10 and 50 thousand megacycles. For calm seas the scattering cross-section may decrease by four orders of magnitude as the incident angle increases from 0 to 60°. The scattering cross-section for horizontal polarization was found to be less than for vertical polarisation at grazing incidence. The instantaneous amplitudes received simultaneously at different frequencies were found to correlate well. Cross polarization at 24 thousand megacycles was 10 to 20 db below the sea return for vertical polarization. Schooley (111) has presented experimental data in agreement with the following expression for the effective radar cross-section area per unit area of surface :

$$\sigma^0 = \frac{\alpha w^2}{\lambda} \sin \theta$$

where w is the wind speed, λ the wavelength, θ the depression angle, and α a constant depending on the azimuthal direction with respect to the wind vector.

Sea return at 32 cm has been observed between 5 and 35 nautical miles (18). The patchy nature of these echoes is of interest since atmospheric refraction is intricately interwoven into the phenomonon.

For forward scattered radiation at angles near grazing the theory is built up on the assumption that the reflected field is composed of a coherent component and a randomly phased

incoherent component (2, 11, 122). Justification for the random phase distribution assumed for the random component is still wanting. The coherent component is calculated by a formula in which shadowing is not taken into account (1). This theory says that specular reflection by a rough surface becomes that of the smooth surface as the scale height is reduced; thus, rough surface reflection with vertical polarization should be quite low at Brewster's angle.

(*b*) *Irregular Terrain*

Overland foreground studies (20, 130) have shown that small features of the terrain in front of the antenna are important in observed signal behavior and should be allowed for in experiments and antenna siting. It has been found that proper antenna siting may improve the circuit by 15 to 30 db. Changing atmospheric refraction markedly influences the effective roughness of the terrain (130). Errors which occur in the measurement of low angles of elevation may be reduced by erecting a screen to intercept the ground-reflected wave (52). In considering the influence of irregular terrain on the propagation of radio waves, it has been shown that this problem may be replaced by a uniform earth surrounded by an inhomogeneous atmosphere (137). Radar return at near vertical incidence has been studied theoretically and it has been shown that the variation with altitude for pulse-length limited illumination varies from inverse-square to inverse-cube (94).

Difficulties surrounding the theories of scattering of radar wave by irregular terrain remain. Besides the physical optics theories and the phenomenological models for backscatter, artificial models of rough surfaces may be so constructed that a self-consistent evaluation of illuminating fields and surface currents can be made. For backscatter and nonspecular reflection in other directions, eletromagnetic reciprocity and the second law of thermodynamics has been called upon to attack the problem.

Recently, the effects of terrain have been considered in a study of the relative performance of different radar wavelengths for surveillance equipment (48). It is assumed that the ground clutter is independent of the wavelength.

(c) *Trees, Buildings and other Obstacles*

In many applications the limiting factor on line-of-sight paths is the diffraction and attenuation effects produced by the obstacles intervening between the transmitting and receiving antennas. A study of the effect of propagation conditions on television broadcasting coverage has been made for the frequency range between 50 and 1000 Mc/s (118). The path attenuation due to obstacles is approximately proportional to the frequency (108). It has been shown that the value of polarization discrimination factor depends primarily on the perturbation of the field due to diffraction and re-radiation by obstacles in the immediate neighborhood of the receiving antenna (109).

4. — Radar weather

Radar weather developments up to about the time of the Eleventh General Assembly of U.R.S.I. have been previously reviewed (87, 15, 19, 97, 98, 81). Recent developments include :

Displays (71, 80, 40) ;

Study of Precipitation of Cumulus Clouds (8, 44, 103) ;

Investigations of Tornadoes and Hail (99, 120, 13, 49, 54) ;

Snow (35, 71, 5, 90) ;

The Bright Band (83, 5. 132, 133) ;

Meso-Scale Pattern (14, 6, 90, 76) ;

Hurricanes (73, 65, 25) ;

Cloud (33, 102, 133, 74) ;

Angels and Lightning (24, 121, 76, 106) ;

Theory (61, 34) ;

Shape and Depolarization (96, 57, 77) ;

Attenuation (33, 49, 29) ;

To summarize the current status and future outlook of radar weather, the following is quoted from Marshall and Gordon (81).

« Great increases in the operational use of weather radars are just now commencing, both with ground-based radars as exemplified by the CPS-9 program of the USAF and similar civilian plans, and by the extensive airborne installations planned by civilian

airlines. (The airlines installations will be most helpful on congested airways, where wide detours are not possible. In addition to increasing safety and comfort, they will also contribute to economy of operation by avoiding unnecessarily wide detours even when these are permissible). All these operational developments should accelerate the correlation of radar and synoptic information (the value of radar network operations in this connection having already been shown) and permit more extensive comparisons between observations at the new wavelength of 5.7 cm, to be used in some of these equipments, with the 3.2 cm of most of the others. The study of hurricanes is accelerating and there will be increased use of wavelength 10 cm for this. It should be noted, though, that in recent studies some confusion as to the velocity of echo components on PPI display was avoided when samplings in vertical section were available. It is to be hoped that the skies will be so scanned as to provide three-dimensional information, and that improved ways of displaying this information will be devised.

This review has pictured showers and thunderstorms as complexes of fairly simple cells ; initiation of precipitation within these cells is not dependent on growth in the ice phase. It remains to be seen to what extent this simplicity is natural, to what extent it is an idealization. Again, while the ice phase is not essential, it is frequently present, and is then presumably an important factor in both the mechanical and electrical aspects of the storm. The incidence of hail is not well established. On all counts, it is to be hoped that radar can by signal-character or by pattern distinguish between hydrometeors containing ice and those that are purely liquid.

The generation of snow in convective cells even in the apparent absence of instability has been indicated. The patterns obtained by « cloud radar » suggest the existence of ice crystals in water clouds that are not actively precipitating. The role of generation-in-cells in the overall pattern of warm-frontal precipitation situations remains to be explained. The mesmeteorological pattern of snow storms has yet to be related quantitatively to the microphysics of crystal growth, and both of these to the role of nucleation.

Good empirical data are now available on the relationship of the radar-relevant quantity Z to rate of rainfall or snowfall. The

scatter of such data is uncomfortably great for their use, as empirical data, in measurement of precipitation by radar. Studies of size-distributions, particularly when related to radar patterns, should give us an understanding of this scatter and so reduce it, in effect, to make such measurements a more reliable and practicable undertaking. The effect of shape and water-coating on the reflectivity of ice particles is relevant here, too, and it must be borne in mind that existing theories in this fiel are somewhat tentative. Studies of the variation of signal strength with height, notably in the region of the Bright Band, and of polarization phenomena, are an excellent proving-ground for theories of the microwave properties of precipitation particles.

Our present knowledge of attenuation by precipitation is not very good. Relevant to all radar operations and to microwave communication, it seems most reasonable to look to studies in the field of weather radar for better information. The role of attenuation in weather radar is being reduced somewhat by the introduction of the intermediate 5.7 cm wavelength for weather use. Operation at 3.2 cm is of proven utility, however, and will continue, certainly beyond the valid period of this review and probably indefinitely. Suggestions that this may be a more suitable wavelength than still shorter ones for cloud studies are very pertinent; it may be that high power equipment at 3.2 cm, its sensitivity enhanced by efficient integration, constitutes the best hope of practicable cloud radar.

Fluctuations of weather echoes with time are relevant to the efficient integration mentioned above. They have been studied to derive information about turbulence and about the distribution of precipitation particles with terminal speed. The future success of such applications would seem to depend on the most careful assessment of the situations in which such techniques are practicable. »

5. — Topics of interest

It would appear that more information is required on the effect of irregular terrain and inhomogeneous media on the effective area of an antenna.

The macroscopic refractive effects in the troposphere appear to be fairly well established for grazing angles greater than two

degrees. An adequate description of the microscopic phenomena is still wanting.

The detailed effect of shape and composition of hydrometeors on attenuation and scattering of radio waves still remains to be determined.

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Collaboration with the C. C. I. R.

The Plenary Assembly of the C.C.I.R. held in Warsaw in 1956 invited the collaboration of U.R.S.I. in Study Programme n° 90 (V) (Tropospheric wave propagation) which is relevant to the field of Commission II, The text of this Study Programme was published in *Information Bulletin*, n° 100, pp. 53-55 (Nov.-Dec. 1956).

N° 114 — Report on the Work of C. C. I. R. Study Group V at the VIIIth Plenary Assembly in Warsaw, 1956

by R. L. SMITH-ROSE (*Chairman*)

At the Warsaw Plenary Assembly, Study Group V held four meetings which were attended by delegates from some sixteen administrations. The progress made in the study of radio wave propagation through the troposphere was reviewed with particular reference to the application of the results to the improvement of communications and broadcasting services. The titles of the various Reports, Questions and Study Programmes adopted by the Study Group have been printed in *U.R.S.I. Information Bulletin* n° 101, January-February, 1957, p. 57. Special attention is drawn to the continuation of general research on tropospheric wave propagation (Study Programme n° 90), to the investigation of multi-path transmission through the troposphere (Study Programme n° 57), and to the revision and extension of tropospheric wave propagation curves for distances well beyond the horizon (Study Programme n° 55). A new study programme (n° 91) was also adopted under the title « Radio transmission utilising inhomogeneities in the troposphere (commonly termed « scattering »). In view of the present widespread interest in the application of « scattering » techniques for communication and other purposes, the text of this study programme is reproduced below :

« The C.C.I.R.,

considering :

(*a*) that, in various countries, recent experiments, characterized by the use of transmitting and receiving antennae directed

towards the same part of the troposphere, have shown that radio signals in the VHF, UHF and SHF bands can be propagated consistently through the troposphere over unexpectedly great distances, and that, beyond the line of sight, fields are found to be much greater than diffraction theory for a standard radio atmosphere would predict ;

(*b*) that useful signals can in this manner be obtained at distances greater than was formerly expected ;

(*c*) that tropospheric inhomogeneities play an important role in this phenomenon ;

(*d*) that little is known about geographical and topographical influences ;

decides that the following studies should be carried out :

Investigation of this new tropospheric propagation phenomenon, in its widest sense, with a view to the extension of knowledge of :

(1) the variation of signal strength, including depth and rate of fading, with distance and frequency ;

(2) the influence of meteorological conditions, including water vapour, rain and snow on signal strength ;

(3) the character of signals, fading rates, time delays and bandwidths and their dependence on frequency and the propagation medium ;

(4) the efficiency of antennae in relation to size and design ;

(5) the use of spaced antennae for diversity transmission and reception. »

National Committee Reports

Canada

N° 185. — Report of the National Commission II

During the period 1951-52, the Radio and Electrical Engineering Division of the National Research Council carried out an experimental program of radar propagation at a wavelength of 3.2 cm over Lake Ontario. Findings were summarized for the Eleventh General Assembly. Analysis of the data has continued slowly since that date, and a report is now in process of publication. The most significant result of this investigation is the determination of the large seasonal variation in ducting conditions on Lake Ontario. In mid-summer, with a radar 50 feet above the lake, extended ranges are observed 60 % to 79 % of the time ; whereas in mid-winter, ranges were always normal in the range of radar heights covered (0-220 feet). Data have also been gathered on the diurnal variation of extended ranges, the effect of rain, and optimum radar height. On the basis of a correlation between air-water temperature difference and the frequency of ducting conditions, an attempt has been made to extend these results to the other four Great Lakes.

A theoretical investigation of propagation far beyond the horizon was carried out at the National Research Council during the summer of 1954 (11). A conclusion of this investigation is that « partial internal reflections » from a smoothly varying atmosphere are far too small to account for the observed field far beyond the horizon. In a second part of this paper reflections from atmospheric layers are considered. These reflections are of the right order of magnitude to explain the observed fields, but on the basis of other characteristics of the observed field it is concluded that scattering from atmospheric turbulence is a more likely cause.

In 1955 an experimental scatter link operating at 2720 Mc/s was established between Ottawa and Toronto, a distance of

215 miles. This link was continued in operation for 21 months. Yearly median level was found to be 80 decibels below free space with a seasonal variation of about 12 decibels. Measurements of fading rate, diversity distance and aperture-to-medium coupling loss were made. The aperture-to-medium coupling loss measurements were made with an array of six four-foot paraboloids which could be paralleled to form an antenna whose horizontal aperture could be varied between 4 feet and 24 feet in four-foot steps. The fading rate of the signal was found to decrease with increasing antenna size as a result of signal integration across the face of the antenna.

During the summer of 1956 a 90-mile scatter link was operated at 2720 Mc/s between Ottawa and Montreal so that the signal variations could be compared with shower activity as recorded by weather radar at Montreal. There was some evidence that showers along the path enhanced and changed the fading rate of the signal, but there was no specific evidence of scattering by drops comparable to the basic scattering by an inhomogeneous atmosphere.

At the Defence Research Telecommunications Establishment, the Tropospheric Physics Section concentrates on radio wave propagation over short paths through the troposphere, roughly those within line-of-sight. On such short paths the effects of volume scattering due to turbulent inhomogneities can be separated from the effects due to horizontal layers more easily than they can be on long paths. Fast fluctuations in the amplitude of the received signal are being studied, by means of power spectrum measurements. These have revealed the usual existence of an inverse square dependence of the fluctuation power spectrum on fluctuation frequency over a range of several octaves in frequency centered between 0.1 and 1 cps, with a carrier frequency of 500 Mc. Physical considerations demand departures from this law at both very low and very high frequencies. Experiments have indicated such departures, but some experimental considerations make accurate numerical analysis difficult. Such radio studies are continuing, and new experiments are being planned. Related atmospheric measurements have been begun. These include refractive index measurements within the first 200 feet. Other measurements including wind speed and direction, and temperature will be made. These measurements are designed to give

information on the fine structure of the atmosphere, and will be analyzed in terms of power spectra, in a similar fashion to that used in the radio work. Temperature gradient and wind gradient measurements will be made also, so that stability criteria may be studied. The work of this section has two complementary aspects. First, the radio wave propagation conditions themselves are of interest, since they determine the limits of usefulness of radio techniques. It is hoped that the atmospheric studies will throw light on the radio problem. Second, atmospheric turbulence itself is a field of great interest, both practical and scientific. It seems quite likely that radio may prove to be quite a powerful tool for atmospheric turbulence studies.

At the same Establishment, the Lower Atmosphere Research Group devotes most of its efforts to studying the effects of refractive index discontinuities in the « lower atmosphere » (i. e. that part below height 25 km) upon signal transmissions at frequencies above 40 Mc/s. Following is a summary by sub-projects of the group's activities :

(*a*) Oblique Scatter Transmissions

Signal amplitude recording on a 46 Mc/s — 185 mile path and on a 500 Mc/s — 85 mile path has been underway for approximately one year. The records are being analysed for variation in median level and in fading rate during the movement of weather fronts through the transmission paths. Data on the position of each weather front and the refractive index profile through the lower atmosphere are being derived from weather charts supplied by the Department of Transport.

(*b*) Vertically Sounding FM Radar

A 7000 Mc/s FM radar is being constructed for vertical sounding through the lower atmosphere. This radar will have a vertical range resolution of 50 feet and a received signal sensitivity of 165 db below one milliwatt. Work on this radar began during the summer of 1956 ; it is expected that the equipment will be ready for vertical soundings during the summer of 1957. Observations will be made on reflections from the tropopause, lower stratosphere, and layers in the troposphere.

(*c*) UHF Noise in Local Atmospherics and Snow Squalls

Equipment has been set up for monitoring of radio noise at four frequencies between 400 Mc/s and 2000 Mc/s, during local atmospherics and snow squalls. Little information is available on the power spectrum of these noise sources throughout this frequency range, although the noise has been found annoying to communications at frequencies as high as 600 Mc/s.

(*d*) Balloon-Borne Refractometer

A lightweight refractometer is being developed to measure refractive index profiles through layers in the lower atmosphere. (Standard radiosondes do not give this information with sufficient accuracy). The refractometer, when tethered to a balloon, is tracked by a lock-on radar, which then records automatically the position of the refractometer during a sounding flight. Work on the refractometer began during the summer of 1956. A programme of measurements with the refractometer is planned for the summer of 1957.

(*e*) Long-Range Scatter Propagation

Preparations are underway for an experiment during the summer of 1957 to measure the nature of 488 Mc/s signals transmitted from Ottawa to receiving sites at Chapleau (380 miles) and Pt. Arthur (640 miles). A 10-kilowatt CW transmitter with a 28-foot steerable antenna is in operation at Ottawa. Data on the tropopause will be gathered during the experiment for correlation with the recorded signals.

Radar weather studies by the Stormy Weather Group in the Department of Physics of McGill University were summarized in some detail for the Eleventh General Assembly. Since that time, members of the group have compiled a general review of radar weather research (10) and contributed to one on « Radiometeorology » (9). Radar studies of snow-formation have continued (3, 8); these may have some relevance to tropospheric propagation. The rate of fluctuation of radar echoes from snow has been measured and considered theoretically (7), and the distribution of snowflakes with size has been measured and related to that for rain (4). A new system of weather-radar scanning,

combined with re-synthesis of the received signals, permits the display of the precipitation pattern in a set of constant-altitude maps (8).

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Czechoslovakia

N° 171. — Report of the National Committee to Commission II

(*Translation*)

In Czechoslovakia, investigations on tropospheric propagation of electromagnetic waves are made at the Institute for Radiotechnique and Electronics of the Academy of Sciences (ČSAV). Systematic measurements are made by the institutes of the Ministry of Telecommunications : Institute for Telecommunications Researches (particularly the influence of the ground on short wave propagation) and Institute for Communications Researches (transmission line propagation). Some special questions related with ultra short wave propagation are studied in the Research Institutes of the Ministry for Precision Machinery.

The Institute for Radiotechniques and Electronics begun its studies on tropospheric propagation in 1955, and was primarily concerned with investigations on ultrashort wave propagation at long distances. Now, two measuring tracks of 250 and 350 km respectively are permanently in operation. The receiving equipment on both tracks automatically records the average value of fieldstrenght for each hour. Very soon, meteorological measurements of atmospheric fine structure will be made with a special sounding equipment. On the theoretical point of view, a theory of long distance propagation based on atmospheric water vapour discontinuities has been developed. An experimental control of this theory is now being made by measurements on the above mentioned tracks. The first results of these experiments have been presented at the International Conference on the Recent Problems of Propagation in Paris (Sept. 1956). Moreover, average gradients of the atmospheric refraction index in Boheme were determined from radio-sounding data obtained in Prague during these last five years.

Finally, a theory of the reflection on rough surfaces was established, not only to account for ground influences on propagation, but also in view of an application of these theoretical results to the reflection on the tropospheric irregular layers. Next year, a long distance connection on centimetre wave lengths will be inaugurated using the troposphere.

The following publications are concerned with tropospheric propagation :

BECKMANN, P. — Ultrashort wave propagation in heterogeneous atmosphere above the spherical Earth (Sl. O. 1953, nº 6).

BECKMANN, P. — A theory of long distance propagation of very short waves (Sl. O. 1955, nº 3).

BECKMANN, P. — Reflection of very short waves on the humidity discontinuities in the atmosphere (will be published in a special issue of *Onde Electrique*).

Items on reflection and refraction of electromagnetic waves are treated in :

BECKMANN, P. — Problems of reflection of ultrashort waves on rough surfaces (Sl. O. 1953, nº 7-8).

BECKMANN, P. — Refraction of meter wavelength on mountain ridges (Sl. O. 1954, nº 8).

BECKMANN, P. — The reflection of electromagnetic waves and synthesis of media (*Acta Technica* 1956, nº 4).

A paper on the average gradient of the atmospheric refraction index in Boheme is now ready for publication.

France

Nº 210. — Report of the National Committee to Commission II

(*Translation*)

The major part of the investigations on tropospheric radiopropagation is carried in France by the Propagation Dept. of the National Study Center of Telecommunications (C.N.E.T.). Other researches are made by private laboratories (Laboratory of Applied Physics of the « Compagnie Générale de T. S. F. », especially), the Study Services of the various department of the National Defence, and Faculties of Sciences of Universities. Some theoretical problems are studied by the Mathematical Department of C.N.E.T.

An international Symposium on recent problems of radiopropagation was organized in Paris (Sept. 1956) by the French National Committee of U.R.S.I. and the « Société des Radioélectriciens » under the sponsorship of U.R.S.I. This symposium led to fruitful exchanges of ideas between scientists from France and abroad.

1. — Radiopropagation within the horizon

In this field of researches, experimental investigations were conducted on permanent links, of interest owing to their geographical or climatic situation : long distance marine radio-links (4, 11), studies of successive tracks along hertzian beams (46), studies on mixed paths (46), studies on anomalous propagation phenomena in radiodetection (43).

These experimental as well as theoretical researches can be grouped in the following chapters :

1. — *Studies of tropospheric fieldstrength fluctuations*

Several investigators attempted to relate field fluctuations to turbulence phenomena in the propagating medium in the following ways : theoretical studies on the composition of random vectors (7), study of turbulence parameters accounting for fluctuation effects (17), analysis of the fluctuation spectrum by auto-correlation methods (36), interpretation of fluctuations in solar radiation (15, 27). These studies, the results of which rather well agree, show however the necessity of a better knowledge of the characteristics of atmospheric turbulence.

Other studies attack the problem with methods more closely directed towards practical applications : consequences on traffic (14), influence of a diversity system (11, 19).

Problems connected with field recordings led to the elaboration of a statistical method susceptible to fulfill practical requirements more completely than a simple distribution curve, and to allow discrimination of characteristic propagation types (42). Such a method is clearly requested by the theoretical and practical utilization of the radio-links data.

2. — *Influence of the lower atmosphere*

Influence of macroscopic discontinuities in the atmosphere on the propagation within optical distance has been studied in various papers. In the case of vertical discontinuities, experiments over the Mediterranean Sea led to a study of guiding conditions (33). These conditions were also investigated theoretically on the basis of the space wavelength concept (30). The case of horizontal

discontinuities, especially the displacement of frontal masses of air, was studied in connection with fade-outs (18, 39).

An investigation of the consequences of finer discontinuities in the atmosphere led to an examination of focalization or defocalization effects (19).

These various works may be considered as elements of a study on radio-climatology, and allow consideration on the validity limits of certain assumptions concerning linearity or horizontal stratification in the atmosphere.

3. — *Influence of surface irregularities*

Few studies were undertaken in this field. A theoretical work using a conformal transformation to pass from the propagation over an irregular surface to the propagation over a smooth surface with an equivalent irregular atmosphere may be indicated (10), as well as other papers on reflecting surfaces at millimetre wave lengths (24).

II. — Propagation beyond the horizon

Radio-links using trans-horizontal propagation were investigated in some papers ; some studied their general characteristics (12, 21) ; others dealt with specialized aspects such as calculation limitations in given geographical or climatologic conditions (31), or criteria for equipment selection (37) and traffic frequencies (2), on the influence of particular aspects of for fields on classical systems (13), the transmissible bandwidth (29), etc.

The experimental radiolinks especially investigated are the following : terrestrial propagation paths in France, Paris-Fontaine Raoult (200 km, 200 Mc/s) (3), Paris-Poitiers (270 km, 450 and 850 Mc/s, (44) ; radiopaths over sea : Continent-Corsica (150 km, 450 Mc/s) (4), Corsica-Algeria (550 km, 100 Mc/s) (54) ; African paths, Douala-Yaounde (200 km, 150 and 450 Mc/s) (32).

The results obtained led to establish curves giving, to a certain amount, the probable attenuation in the propagation beyond the optical horizon with distance and climatic conditions. However, the dispersion in the experimental data is too great for allowing the « a priori » calculation of a radio-link. The principal parameters seemingly to be defined are the following : influence of the

distance on average attenuation, seasonal effect, characteristics of rapid fluctuations, effect of extremities obstruction, climatic influence.

Some theoretical interpretations of the long distance propagation resulted from an effort to gain some precision on the spherical diffraction (34) and to deal with the case of a non-linear atmosphere (53).

But the major part of the theoretical researches are concerned with the scattering of waves in the atmosphere. The role played by atmospheric turbulence was investigated from various points of view : selection of the proper turbulence parameters for experimental observations (17), comparison of various turbulence models (8, 10*bis*), spectral interpretation of scattering (10*bis*, 29, 30). Auto-correlation functions of the field fluctuations were related either with velocities of scattering elements (40), or with the turbulence spectrum (36).

Measurements by means of a refractometer led to a comparison between meteorological turbulence and fluctuations of the refraction index.

Other studies were made of the influence of partial reflections (25), and of thin stratification layers in the atmosphere (26).

2. — *Propagation over mountain ridges*

Various paths of great length with a mountain ridge as horizon at both extremities have been studied, especially Bone-Bouzizi in Algeria (100 km, 500 Mc/s) (49), Mt Ventoux-Mt Agel in the Alps (180 km, 2000 and 3000 Mc/s) (49), Martinique-Guadalupe beyond and before the Dominique Island (190 km, 90 Mc/s) (50).

These links showed evidence of a lower attenuation for the same distance, than in the absence of a common horizom. It seems that the fields are stable during the major part of the time, though rather quick fadeouts may occur at certain periods.

Propagation phenomena over an irregular surface were studied on the basis of a comparison between the influences of ground irregularities and atmospheric irregularities (10), and on the basis of theoretical computations for the case of a ridge shaped as a parabolic cylinder (55).

III. — Radiometeorology

In addition to the above mentioned studies on relations between meteorological conditions and attenuation in paths expended within and beyond the horizon, the principal works in radiometeorology may be grouped under the two following rubrics :

1. — *Radio-climatology*

An effort has been made for establishing a valuable relation between climatic regions and propagation conditions. The preliminary work consisted in determining the most suitable meteorological parameter to account for meteorological situation in the lower atmospheric layers. The choice of the index-gradient seems more appropriate than the refractivity at ground. An analysis of the data obtained during the last years in France and the Overseas territories led to predictions of climatic influence ; these predictions were succesfully compared with radio-link observations, unfortunately in unsufficient number. The climatic influence on transhorizontal links in various countries of Europe and Africa might be of the order of 20 db (31, 47).

To radiometeorology, may be associated the development of a radiosounding equipment permitting detailed measurements (20) and a study on the index definition from meteorological date (35).

2. — *Use of propagation data for meteorology*

Investigations are continued with ultra short wave radars for meteorological purposes, especially for rain studies (51). A theoretical interpretation of the effect of an electromagnetic field on rain drops may also be indicated (23).

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Germany

N° 191. — Report of Commission II of the National Committee

1. — Papers on theoretical studies

1.1. — *Theoretical articles on particular problems*

Particular problems of the tropospheric wave propagation have been discussed in a number of theoretical articles (1-7) with particular reference to distances well beyond the horizon.

1.2. — *General surveys*

The substance of the manifold German and foreign literature on propagation beyond the optical horizon was summarized and clearly arranged in some articles (8-11).

2. — State of propagation research in the metric wave band

2.1. — *Distribution with time of the field strength*

Most of the 22 test paths for statistical field strength observations existing at the beginning of the period under report were broken up. Measurements and evaluations on the remaining paths could thus be intensified. Recordings have been made by means of statistical counters (Recording the half-hourly distribution with time) or by means of ink recorders, the recording slips of which have been evaluated by semi-automatic scanning devices. A fully automatic scanning device allowing the use of an electronic computer is in development.

Apart from a minor drop at great distances, the dependence of the measured median values on distance corresponds approximately to the C.C.I.R. curve (12-23). There is a maximum of the mean deviation at about 250 km. The half-hourly distribution curve agrees with the Rayleigh distribution, this being independent of the fading frequency. A variation of the fading frequency with the distance was not observed.

The diurnal variation of the field strength is stronger over land than over sea, whereas the seasonal variation is stronger over sea.

2.2. — *Correlation with meteorological conditions*

Only in individual cases it was possible to correlate the field strength curve with the meteorological data. Statistically there seems to be a better relation to the vertical gradient of the atmospheric pressure (24). The correlation of the fading frequency with meteorological conditions is, however, more obvious than that of the field strength (25-29).

This year we will begin with field strength recordings on the path Torfhaus — Kiel at the same time measuring the meteorological data by means of captive balloons at two places.

The metric wave wind velocities determined according to the

method of ionospheric drift measurements correspond to the tropospheric distribution of wind (30).

2.3. — *Propagation over mountain ridges*

The increase in field strength caused by diffraction at sharp edges in the Alps was measured during some months (31).

2.4. — *Distribution with location of the field strength*

In order to determine the deviation with location valid for the area of Federal Republic recordings in streets and point measurements on roofs were carried out (32). These measurements are extended to all existing geographical and constructional structures by simultaneously employing six test crews.

2.5. — *Depolarization*

The depolarization resulting from scattering and diffraction in the troposphere is negligible compared with the orological influences near the receiving point (hills, buildings, trees) (33, 34).

2.6. — *Height dependence, angle of incidence*

At a distance of 225 km receiving field strengths were measured, being from about 10-25 m onwards independent of height. This corresponds to an angle of incidence of 2°-4° of the scattered radiation (35).

2.7. — *Determination of the radiated power by means of field strength measurements*

Determination of the actually radiated power by means of field strength measurements is only possible when the receiving field is free from reflection components. The error resulting from slope reflections near the transmitter decreases with increasing distance (36).

3. — State of propagation research in the decimetric and centimetric wave bands

3.1. — *Distribution with time of the field strength*

Recently investigations have more and more been carried out on shorter waves. At the time being there are the following test paths :

Hornisgrinde-Darmstadt (142 km, 500 Mc/s), 2 transmitters at different heights above ground;

Hornisgrinde-Darmstadt (142 km, 7 km c/s);

Torfhaus-Berlin (195 km, 2 km c/s).

The paths

Torfhaus-Darmstadt (255 km, 500 Mc/s);

Hornisgrinde-Darmstadt (142 km, 4 km c/s);

Hornisgrinde-Darmstadt (142 km, 9 km c/s);

Helgoland-Sahlenburg (61 km, 2 km c/s);

Helgoland-Weddewarden (79 km, 7 km c/s);

are being established.

First results are already available (37-39).

3.2. — *Correlation with meteorological conditions*

Measurements of the fine structure of the lower atmosphere have been carried out by a great number of personnel at the same time as the field strength recordings over sea within the Heligoland Bight. The dependence of the radar ranges over sea on the M profiles was investigated by means of 3 cm Decca equipment (approximately 7000 measurements) (40-42).

4. — Meteorology

The atmospheric stratification over sea was investigated with the help of profile measurements of the water vapour content of the air and of refraction measurements within the optical range (43, 44). A method for the calculation of the M profile was derived therefrom (45).

Meteorological observations and cloud physics investigations were made by radar (46, 47). With the majority of convection precipitations a strongly reflecting layer was located, whose position to the ice point and relation to the upper boundary allows conclusions to be drawn on the process of starting precipitation.

A climatology of the M values and gradients up to a height of 3 km in Northern Germany is about to be completed.

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Italy

Nº 160. — Report of the National Committee to Commission II

From July 1954 to June 1957, various experiments on tropospheric propagation were conducted in Italy, especially by private Compagnies, but generally in order to fulfill orders requirements

for herzian beams to be operated by the State or by organizations depending from the State.

A survey on these experiments is reported below (1), followed by a bibliography whose articles contain the major part of the information (see reference numbers); in addition a number of papers on theoretical researches and various subjects are listed.

1. — Radiopropagation within the horizon

1.1. Naples-Capri (32 km) on 585-685 Mc/s (M. M.).

Owing to the occurrence of very high and pronounced ducts and in order to avoid very deep fadings, it was necessary to lower the Capri station and to place it (as well as the Naples station) at an altitude inferior to the minimum height of the duct in which the given frequency could be trapped (unpublished).

1.2. Milan-M. Cimone (185 km) and M. Penice-M. Venda (195 km) on 1000 Mc/s (M. M.).

During 99 % of the time, fading depths not superior to 13 db (with respect to the median fieldstrenght) in winter conditions, and to 17 db in summer conditions (Bibl. ref. 1.2) were measured.

1.3. Milan-M. Cimone on 250, 500, 1000 Mc/s (M. M.).

Slow fadings are approximately the same on the four frequencies; rapid ones increase with frequency. Other experiments showed that fadings also increase with distance (Bibl. ref. 1.3).

1.4. Trivero-Milan (87 km) and Trivero-Caravaggio (120 km) on 1000 and 4000 Mc/s (M. M.).

A special report on these results will be presented to the General Assembly .

1.5. M. Argentario-M. Limbara (230 km) on 800 and 1000 Mc/s (M. M.) and on 200 Mc/s (S. F.).

The R. A. I. (Italian radiotelevision) promoved these experiments in view of an extension of the T. V. programs to Sardinia. Encouraging results were obtained (unpublished).

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(1) (M. M.) = Magneti Marelli, Milan; (S. F.) = group SIRTI-FACE, Milan; (M.) = Microlamdba, Naples.

Owing to limited scope of this report, we will not describe experiments made by other Societies and Institutes.

1.6. Broadband hertzian beam (for television and multiplex telephony) between Rome and Pescara on 4000 Mc/s (M. M.).

This beam is being put in operation for the « Azienda di Stato Servizi Telefonici ». Fieldstrength recordings were effected during the summer of 1956 on different tracks (lengths up to 60 km) (Bibl. ref. 1.6).

1.7. Cuneo-Colle Maddalena-Torino on 2500 Mc/s (S. F.).

Statistical field distribution on this beam in operation was established from an analysis of records obtained during a long period (Bibl. ref. 1.8).

1.8. Camaldoli-Ventotene (63 km) and Camaldoli-Ponza (103 km) on 6250-6425 Mc/s (M).

During the Autumn of 1956, a median value of 2 was found for the terrestrial radius effect (unpublished).

2. — Radiopropagation beyond the horizon

2.1. Sardinia-Minorque on 300 Mc/s (S. F.).

Systematic records in various meteorological conditions were obtained. Median values in agreement with the predictions of the theory on tropospheric scattering were found (Bibl. ref. 2.1). These experiments will be continued on 900 Mc/s (S. F. Ing. Niccolai and Ing. Bonavoglia).

3. — Theoretical researches — Miscellaneous subjects

Optical propagation (3.4, 3.6). Non optical propagation (3.5, 3.8, 3.9). Passive reflectors (3.7). Statistical description of fluctuating electromagnetic fields (3.1, 3.2, 3.10). Measurements of fluctuating e. m. fields with electronic counters (3.3). Radar-meteorological investigations (3.11).

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Japan

N° 198. — Report of the National Committee to Commission II

by H. HATAKEYAMA and K. ISONO

Series of experiments (1, 2, 3) on obstacle gain of mountain have been carried out by the Radio Research Laboratories. VHF and SHF waves emitted from Tokyo were received behind the Mt. Fuji, Mt. Mikuni and Mt. Yamizo. The reverse routes were also examined. The results of the experiment show that the obstacle gain is so remarkable that the long span wireless communication by VHF is possible when high mountain is in the middle

point of the routes. Experiments of long distance propagation (400 km to 300 km) were also carried out.

Over-sea propagation tests of VHF waves were carried out between Kokubunji and Hachijo-island. The effect of radio duct appeared frequently. Over-sea tests were also carried out between Hiraiso and Inubo, using 10 000 Mc/s, 150 Mc/s and 60 Mc/s waves (4, 5).

The Technical Research Laboratory of NHK conducted tests (6, 7) of the waves of three TV stations in Tokyo, JOAK (103.25 Mc/s, 63.5 kW), JOAX (171.25 Mc/s, 100 kW) and JOKR (183.25 Mc/s, 100 kW) on the summit of Mt. Tokin (676 m above sea level), Niigata Prefecture, in summer and autumn of 1956. Over-sea tests of VHF and SHF were also carried out between Tokyo and Tateyama.

The variation of M-profiles with time has been continuously observed up to the heights of 300 meters above the ground on a broadcasting antenna tower by the Electrical Communications Laboratory, Nippon Telegraph and Telephone Corporation. M-profiles observed were compared with records of fading obtained simultaneously of 4000 Mc/s wave. Propagation tests by means of multiray measuring devices using frequency sweep method (frequency range 3850 $\pm$ 250 Mc/s) along two line-of-sight paths, one of which was parallel to the earth's surface and other was oblique, were conducted by the Electrical Communication Laboratory. The Laboratory also conducted experiments on diffraction of electromagnetic waves by a dominating ridge and on the propagation of VHF beyond horizon.

Railway Technical Research Institute, Japanese National Raylways, has carried out tests on over-sea propagation (6720 Mc/s) between Hakodate and Sapporo and on over-land propagation between Tokyo and Osaka.

Theoretical investigations on tropospheric propagations have been made by many investigators. Propagation across boundaries separating different media was discussed by Furutsu (8, 9, 10). The relation between atmospheric turbulence and scattering of electromagnetic wave was discussed by Tao (11). Tukizi made theoretical investigation of scintillation fading (12, 13). Effects of meteorological conditions have been investigated by Hirao, Tao and Baba (14, 18).

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Netherlands

Nº 166. — Report of the National Committee to Commission II

The National Committee has no important work to report to Commission II since the last General Assembly in the Netherlands.

The only ones that ought to be mentioned are those made at Dr. Neher's Laboratory of the Dutch PTT in Leidschendam.

From August 1 to December 31, 1955, fieldstrength measurements were made with simultaneous recording of both polarizations on the sound channel of the TV-transmitter « Sutton Coldfield ».

The carrier frequency was 58.25 Mc ; from available information, the radiated power was 20 kW (apparent).

The transmitting antenna, at a height of 224 m, radiated a vertically polarized field, the distance between transmitter and receiver was 460 km ; the receiving antennas, of the Yagi type, were placed at a height of 48 m.

In every case when horizontal fieldstrengths have been measured, the interval between vertically and horizontally polarized components of the field was approximately 18 db. Fieldstrengths deduced from an analysis of the records obtained were 26.4 db (with respect to 1μV/m) and 20.1 db for values of 1 % and 10 % respectively. These figures are greater than those given by the curves of the C.C.I.R. advice nº III, *London* (document 267, VIIIth Plenary Assembly of the C.C.I.R., Warsaw, 1956).

New Zealand

Nº 157. — Report of the National Committee to Commission II

(1) Work has been carried out on propagation conditions of microwave transmissions using an optical path (65-70 km) very largely over sea water, but with a knife edge mountain ridge theoretically cutting of the sea reflected rays from the receiver.

(2) Observations have been carried out on the spectrum of

back scatter from the sea surface using a doppler radar system at 13.5 Mc/s. This work has been published (1).

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Poland

N° 205. — Report of the National Committee Radio and Troposphere

In Poland, interest in the field of ground and tropospheric wave propagation centres on the following topics :

1. *Analysis of methods for calculating the propagation of radio waves over inhomogeneous earth.* — According to Z. Godzinski's theoretical investigation (1, 2) an extension and generalisation is made of Feinberg's theory to the case of inhomogeneous spherical earth. The computation of the field is based on a new approximate method of equivalent secondary sources. The Millington's method and the equivalent numerical method have been compared with theory (3).

2. *Study of the structure of the earth inhomogeneities from the point of view of electrical conductivity.* — This conductivity or the electrical resistance are measured by means of the methods used in geological research (see the example, fig. 1). The structure obtained of the earth inhomogeneities is available for confrontation with the field strength anomalies of the broadcast wave propagation.

3. *Study of very long electromagnetic waves caused by the fluctuations of the geomagnetic field.*

4. *Observation of signals coming from distant ultra-short wave stations.*

5. *Study of fadings.*

6. *Observation of the variability and fluctuation of the propagation path in ultra-short wave communication* (4).

7. *Measurements of the tropospheric scatter propagation in Poland* (5).

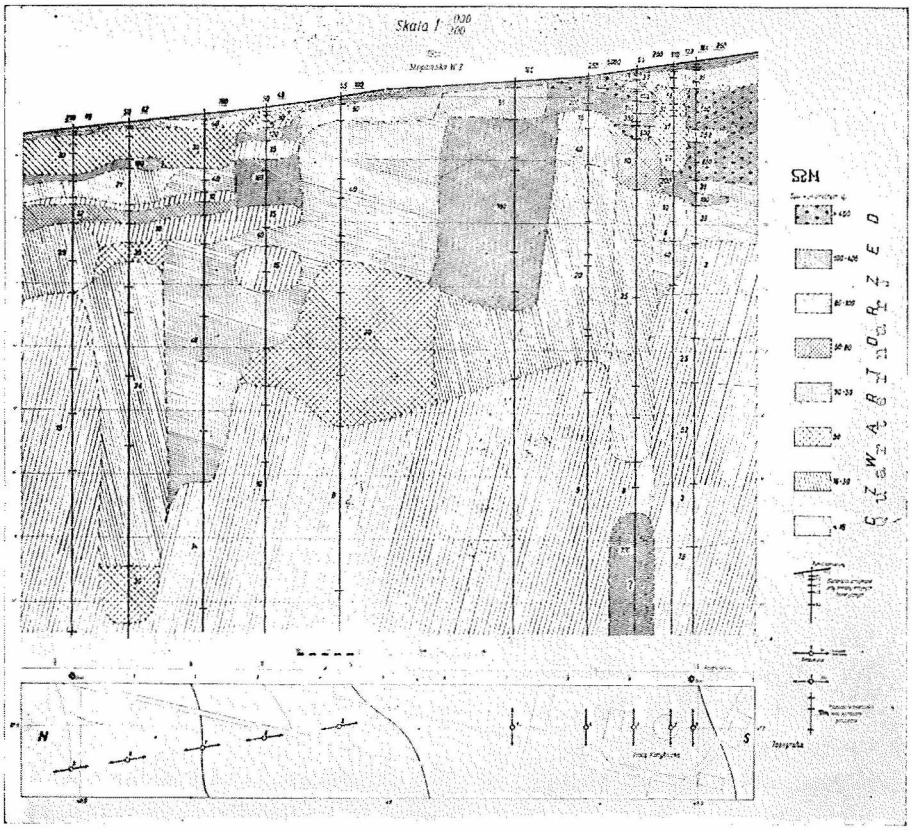


FIG. 1. — Geological Measurements in the Region of Wola Korytnicka, Poland.

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Sweden

N° 214. — Report of the National Committee

(Martin Fehrm)

Research work within the field of the Commission is done at the Research Institute of National Defence and at the Royal Board of Telecommunications. Several topics, which were recommended at the U.R.S.I. General Assembly in the Hague have been studied, and some of this work is summarized in separate reports which are submitted for presentation at the coming General Assembly. The titles of these reports are given below.

Royal Board of Telecommunications

1. Short term measurements and surveys of field strength is being made from FM broadcasting stations in band II (87.5-100 Mc/s) and of television stations in the bands I (54-88 Mc/s) and III (174-216 Mc/s). The measurements refer to distances up to about 150 km.

2. Continuous recordings of field strength — in some cases since several years — is made from FM transmitters in band II at distances ranging from about 60 km to about 200 km, and on two radio links working in the 170 Mc/s band with propagation paths of about 100 km length, mainly over sea.

Research Institute of National Defence (FOA)

1. Wave propagation far beyond the horizon has been investigated. From continuous recordings of field strength a statistical analysis is made of the time and distance dependence of the signal and of other signal characteristics, which are of importance for communication applications. These measurements are made at 10 cm wavelength.

2. The influence of meteorological factors on microwave propagation has been studied experimentally. In particular the aim of this work has been to find simple methods of predicting radar coverage based on meteorological prognoses.

3. The influence of reflections from low tropospheric layers over hilly terrain on microwave field strength just below the horizon has been studied. The diurnal and seasonal variations of the probability of existence for such layers is also investigated.

4. Propagation within the horizon at low heights has been studied within the frequency range 30 Mc/s-100 Mc/s. The main factors affecting such propagation — effective dielectric constant of the ground, topography and vegetation — have been investigated separately. Special attention is paid to seasonal variations of the dielectric constant as influenced by the water content of the ground.

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1. G. Carlson (FOA). — Long-distance communication by wave scattering. *Teknisk Tidskrift*, nº 41, 1956, pp. 947-953. In Swedish.

2. B. Josephson, G. Carlson (FOA). — Distance dependence, fading characteristics and pulse distortion of 3000 Mc/s trans-horizon signals (Submitted paper), nº 176.

Summary. — Statistical analysis of signal recordings at 10 cm wavelength has given the following results.

The distance dependence of the half-hour signal median F*m* over a sea path corresponds to a scattering parameter which is approximately inversely proportional to the height. Between F*m* and the surface value of M a correlation coefficient of 0.62 is found, and between F*m* and the dew point 0.55. A unit increase of M seems to be followed by a signal increase between the limits 0.3 and 0.8 db. The fading range, as defined between the 10 % and 90 % of time levels, is 12-14 db, and the fading frequency mostly about 2 kc/s for a 300 km path.

Over a 260 km land path the pulse broadening was normally 0.1-0.2 μs which corresponds to a scattering parameter varying inversely as the 1st-2nd power of the height. A severe pulse distortion caused by selective fading is found to be very common.

Some other propagation characteristics are also discussed.

3. B. Josephson, F. Eklund (FOA). — Some microwave propagation experiences from a « just-below-horizon » path (Submitted paper), nº 175.

Summary. — Based on comparisons between field strength records at 2300 Mc/s and simultaneously measured M-curves it is concluded that the most important propagation disturbances on the test path are caused by reflections from discontinuities in the refractive index profile. The occurrence probability for such discontinuities is shown to have a marked seasonal and diurnal period with a maximum in the summer and around sunrise.

4. B. Josephson (FOA). — Wave propagation over homogeneous ground. Tele (Stockholm), nº 2, 1956, pp. 49-56, 71. In Swedish.

5. S. Gejer (KTS). — Wave propagation conditions at meter- and decimeter-waves, with special reference to broadcasting and television transmissions. Tele (Stockholm), nº 2, 1956, pp. 57-63. In Swedish.

6. B. Josephson, A. Blomquist (FOA). — The influence of moisture in the ground, temperature and terrain on ground wave propagation in the VHF-band (Submitted paper), nº 174.

Summary. — Results are given from a general investigation regarding the different factors that govern VHF ground wave propagation at low heights and short distances, i. e. mainly in the Sommerfeld region. In this work the influence on field strength from ground moisture and temperature, snow, topography and vegetation, and also field strength variations along mixed land — water paths have been studied. The measurements refer to terrain typical for middle Sweden.

Suitable formulas for field strength calculations over smooth ground are developed. The moisture in the ground is found to play a principal role and a method is shown for calculation of changes in the path attenuation caused by known or predicted changes in the water content of ground. The influence of temperature is found to be small, even when the ground freezes, but a covering of snow may be of greater consequence. Characteristics of local variations and exponential attenuation of the field in a forest is demonstrated, the fluctuations being very large and the average exponential attenuation factor mostly very small. Measurements along a mixed land to fresh-water path verifies Millington's recovery effect. The field over a hill is found to have a maximum value a certain distance below the top towards the transmitter.

7. A. Blomquist (FOA). — Fieldstrength prognoses of VHF groundwave propagation. RVK-1957. In Swedish.

8. F. Eklund (FOA). — Semi automatic curve analyzer for fieldstrength statistics. RVK-1957. In Swedish.

Switzerland

Nº 140. — Report of the Swiss National Committee to Commission II

Dr. Gerber

1. Messrs Jean Lugeon and Max Bohnenblust made some new experiments about the propagation of waves of 3 m and 80 cm wavelength transmitted by radio-meteorographs to the federal aerologic station of Payerne. The waves were modulated to transmit the gradient of potential and the conductibility of the air up to an altitude of 25 km.

The reception on the ground station revealed some interesting and apparently new fluctuations of the transmission field. Several times, and for some still unexplained reasons, the transmission field fell very quickly to raise again to its normal value in some tenths of second.

It seems to be not impossible that this phenomenon is due to an effect of interference in the vertical sense between the superposed masses of air, having different geographical origins. The phenomena of high absorption are registered on apparates of high sensitivity at the ground station.

The investigation in not yet terminated. It will be continued during the International Geophysical Year as well in Payerne as at the Swiss Station in the north of the Spitzberg's Archipelago.

2. During the above mentioned period the group for the study of tropospheric propagation of the Swiss PTT has been mostly occupied with the choice of the places for transmitters of our national network of FM and television in the bands I, II and III. Though these investigations have first of all a practical purpose, they allowed to make interesting remarks about the distortion due to the multiple propagation in the hilly regions.

At present, similar measurements are prepared in the two bands IV and V of television.

Moreover, the laboratories of research of the PTT made the following investigations :

3. The fields of some ultra-short wave-transmitters of Italy have been measured in the north of the Alps and compared with the theoretical values for the hypothesis of a spherical earth.

Some cases of « barrier-gain » have been observed especially for the rays passing the highest summits of the Alps as Mont-Blanc, Nesthorn, Eiger and Jungfrau. A gain of 10 db is not seldom, a gain of 20 db has been observed in one case (F— 67, 75 Mc/s distance : 250-300 km).

4. For the study of the fine structure of the inferior layers of the troposphere different radio-meteolorographs using very small thermistors, in order to obtain a small timeconstant, have been developed either for investigations with helicopters or with captive balloons.

The thermistors used as resistance of RC-oscillators give fre-

quencies of modulation in function of the temperature and of the humidity.

The measurements are made in a continuous way, which allows to observe some reversal layer of small depths.

5. Some analyses of the propagation of waves of 15 cm wavelength on three alpine distances (starting from the Jungfraujoch, 3690 m above sea level) showed a higher stability than on similar distance at lower altitude. Similar detailed studies have been made with 4000 Mc/s-waves for a distance of 127 km, to study especially the effect of polarization and of the diversity of frequencies.

United Kingdom

N° 123. — Report of the National Committee on Tropospheric Wave Propagation

Further progress has been made in the United Kindgom during the past three years in the study of radio wave propagation at very high frequencies, both within and beyond the horizon, as influenced by the nature of the terrain and by conditions in the troposphere. Meteorological investigations relevant to various aspects of wave propagation have been pursued, and new determinations have been made of the refractive indices of atmospheric gases. A summary of this work together with a bibliography of published papers is given below.

1. — Propagation over Optical Paths and Effects of Irregular Terrain

A feature of millimetre-wave propagation of considerable interest is the absorption band due to oxygen which is centred on a wavelength of 5 mm. Work on this absorption has previously been confined to laboratory investigations, and the experiments, described by W. E. Willshaw, H. R. L. Lamont and E. M. Hickin (1), in which measurements were made with transmissions over a distance of a few km at wavelengths in the range 4 to 6 mm, form a valuable addition to knowledge in this field. In these experiments observations were also made of the reflection coefficient of the sea surface for millimetre waves, the results being consistent with what would have been expected on the basis of the Rayleigh criterion of surface roughness.

D. G. Kiely (2) has examined the characteristics of rain echoes (« clutter ») obtained with continuous-wave radar systems operating at a wavelength of 8 mm. The clutter was found to be much greater with a system having a common transmitting and receiving aerial than with one in which separate aerials were used for transmission and reception.

Investigations in the 40 to 200 Mc/s band of the discrimination likely to be achievable between common-frequency transmissions by the use of orthogonal polarizations have been made by J. A. Saxton and B. N. Harden (3). The discrimination appears to be determined primarily by the topographical nature of the receiving site, and is substantially independent of distance from the transmitter and of frequency in the band specified above. Furthermore, there is no evidence of rotation of the plane of polarization in transmission through the troposphere. With a carefully constructed receiving dipole the median value of the discrimination was found to be 18 db : this value could, however, be materially affected by aerial misalignment and by pick-up on the aerial feeder. A value near this was accepted internationally by the C.C.I.R. on the advice of its Study Group V, which is concerned with this matter (4).

Whilst the attenuation caused by a few trees in a transmission path at V. H. F. and U. H. F. may not be serious, quite significant attenuation can be caused by thick and extensive woods, as has been shown by the work of J. A. Saxton and J. A. Lane (5). This work also included an investigation of the diffraction effects produced by trees and buildings, and their importance in relation to the selection of sites for good reception.

The bearing of the ground-wave propagation studies mentioned above, and others, on broadcasting, particularly for television, has been discussed in papers by R. L. Smith-Rose (6, 7) and J. A. Saxton (6, 8).

2. — Long-Distance Tropospheric Propagation

M. W. Gough (9) has presented an analysis of extensive continuous V. H. F. field-strength measurements made in tropical and Mediterranean regions covering a period of four years. The results of this work well illustrate some of the established mechanisms of tropospheric propagation, and the importance of the results to communication engineers is brought out. In some

instances it was found possible to deduce from the signal records the salient features of the refractive index-height profiles which must have existed at the time of the observations. A limited connection was found between median path attenuation and fading range for paths experiencing comparable tropospheric influences which, with some reservations, should make possible the approximate forecasting of the statistical behaviour of radio links without assistance from a preliminary radio survey.

An investigation in which field strengths at 91 Mc/s were measured, using an aircraft, at a height of 3000 metres and at distances well beyond the horizon up to 700 km, has been described by B. J. Starkey (10). The analysis of the results obtained, and their correlation with meteorological data, suggest that many phenomena of long-distance propagation could possibly be explained by the simple hypothesis of specular reflection from temperature-inversion layers at the tropopause.

J. A. Saxton, K. S. Kreielsheimer and G. W. Luscombe (11) have given a description of a technique, involving a simple system of telemetry, for measurements of the variation of the field strength of metre-wave transmissions with height above ground. Transmission distances of 60 to 500 km were investigated with frequencies in the band 40 to 70 Mc/s, and the field strength distributions were determined up to heights of 1500 metres. This work has shown that at a distance of 150 km, with a frequency of 58 Mc/s, the observed height-gain under conditions of standard refraction is very similar to that predicted by diffraction theory; but divergences from this theory occur when non-standard modes of propagation obtain. On the other hand, for appreciably longer paths it appears that the median height-gain over a given interval of height decreases as the transmission distance increases. This is what would be expected if the propagation is primarily due to reflection from elevated inversion layers, or to scattering in the troposphere.

A detailed theoretical treatment of the radio scatter propagation problem has been given by the late E. C. S. Megaw (12). In this work the manner in which the fluctuations of refractive index vary throughout the troposphere is assumed to be similar to that of the corresponding velocity fluctuations. On this assumption the spatial distribution of the refractive index fluctuations is

derived from the universal theory of turbulence. Analysis of observations of stellar scintillation has provided confirmation for this theory. Measurements have also been made of radio field strength variations over line-of-sight paths, and these, together with the stellar data, have been used to determine the manner in which the magnitude of the refractive index fluctuations varies with height. Megaw's new theory has provided a more satisfactory explanation than earlier theories of experimental work at a wavelength of 10 cm carried out by him in 1949.

At the VIIIth Plenary Assembly of C.C.I.R. in Warsaw, 1956, a new Study Programme was introduced to encourage the investigation of tropospheric scattering (4) ; and in this connection it may be added that such investigations, for frequencies in the range 800 to 10 000 Mc/s, are in progress in the United Kingdom.

3. — Meteorological Investigations

The characteristics of atmospheric turbulence have been investigated by several workers. F. J. Scrase (13) has given an account of data, derived from radar-wind and radiosonde measurements, which shows the fluctuations, minute by minute, of wind components and temperature at heights up to 30 km ; whilst R. F. Jones (14) has obtained information on the detailed structure of vertical air currents within clouds from measurements made in an aircraft with an accelerometer. E. C. S. Megaw (15) has discussed stellar scintillation in relation to turbulence, and has indicated the usefulness of studies of this scintillation for the derivation of information concerning the fluctuations of atmospheric refractive index which influence wave propagation. It has further been shown by R. S. Scorer (16) that, if standing waves occur in the atmosphere, clear-air turbulence is to be expected at levels where there are discontinuities of shear in the airstream.

An examination has been made by F. J. Scrase (17) of the performance of the radiosonde in relation to the determination of the diurnal variation of upper-air temperature. It appears that errors of the radiosonde can account for the observed differences between day and night measurements at heights up to 15 km : above this height, however, the differences are appreciably greater than the errors, and they suggest that the daily range of temperature variation over the British Isles in Spring and Autumn is

about 1.5° C at 20 km height and 3° at 25 km. An investigation of the variation of temperature in the troposphere and lower stratosphere, using radiosonde data, has also been described by J. K. Bannon and A. Gilchrist (18).

R. J. Murgatroyd, P. Goldsmith and W. E. H. Hollings (19) have made experiments at heights up to 15 km over Southern England in an aircraft, in which a pressurized Dobson-Brewer hygrometer was used to make measurements of humidity. The observations showed that the frost point decreases with increasing height from a somewhat variable value at the tropopause to a fairly constant value of about —83° C at levels of 3 to 5 km above it.

4. — Atmospheric Refractive Index, and Precipitation Studies

L. Essen (20) has made further studies at centimetre wavelengths of the refractive indices of atmospheric gases ; and his work has demonstrated that the absorption line in water vapour at 22 000 Mc/s has a negligible effect on the refractive index. Measurements of a similar nature have also been made by W. Jasinski and J. A. Berry (21).

In 1954 a comprenhesive survey of knowledge concerning the physics of rainclouds, and of outstanding problems in this field, was presented by I. C. Browne, H. P. Palmer and T. W. Wormell (22). They pointed out that, although cloud physics had reached a stage at which the various processes leading to rain were understood qualitatively, there was still much to be found out about the actual conditions existing inside rain clouds, and they indicated how radar echo investigations might be of assistance in this respect. Since that time a number of such investigations have been made by B. J. Mason (23, 24, 25), Ramanadhan (23) and P. J. Feteris (25). The modification of the size-distribution of falling raindrops by coalescence has been examined, and radar evidence for the aggregation and orientation of melting snowflakes has been obtained. This latter work has shown that, in general, each snowflake in the melting zone coagulates with one or more (on average two) others of much the same mass to form horizontally oriented aggregates which scatter as oblate water spheroids of mean diameter-to-axis ratio 4.

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U. S. A.

N° 296. — Report of the National Commission II

During the last three years tropospheric propagation studies in the United States have emphasized : ground wave propagation over mixed paths, propagation of the phase of the ground wave, propagation of transient ground waves, correlation of the fields received in propagation over irregular terrain, ray bending within the normal horizon, effect of terrain and medium on the capture

cross-section of antennas, phase and amplitude measurements within the horizon, measurement of radio fields well beyond the horizon, prediction of radio fields from standard meteorological measurements, absorption of radio waves in propagation through the atmosphere, and theoretical attempts to describe the observed phenomena.

A. — Meetings at which tropospheric phenomena were discussed include

1. Sept. 8-10, 1954 : Dedication of Boulder Laboratories, Boulder, Colorado.
2. March 21-24, 1955 : I.R.E. National Convention, New-York, N. Y.
3. May 2-5, 1955 : U.R.S.I. Spring Meeting, Washington, D. C.
4. June 20-25, 1955 : Symposium on E-M Wave Theory U.R.S.I.-University of Michigan, Ann Arbor, Michigan.
5. July 5-7, 1955 : Symposium on Normal Mode Theory, San Diego, California.
6. Aug. 24-26, 1955 : I. R. E.-WESCON, San Francisco, California.
7. Nov. 14-15, 1955 : Symposium on Communication by Scatter Techniques, Washington, D. C.
8. Dec. 15-17, 1955 : U.R.S.I. Fall Meeting, University of Florida, Gainesville, Florida.
9. Feb. 2-3, 1956 : National Symposium on Microwave Techniques, Philadelphia, Pennsylvania.
10. Mar. 19-22, 1956 : I.R.E. National Convention and Radio Eng. Show, New-York, N. Y.
11. April 11-13, 1956 : Seventh Region Technical Conference, Salt Lake City, Utah.
12. April 30-May 3, 1956 : U.R.S.I. Spring Meeting, NBS, Washington, D.C.
13. Sept. 1955 : Fifth Weather Radar Conference, Signal Corps Engineering Laboratories, Ft. Monmouth, N. J.
14. Aug. 21-24, 1956 : I. R. E.-WESCON, Los Angeles, California.
15. Sept. 6-7, 1956 : Conference on Refractive Index Measurements, M.I.T. Lincoln Lab. and Air Force Cambridge Research Center (Summary : *Trans. I.R.E.*, AP-5, p. 147, Jan. 1957).
16. Oct. 11-12, 1956 : U.R.S.I. Fall Meeting, Berkeley, California.
17. March 18-21, 1957 : I.R.E. National Convention and Radio Eng. Show, New-York, N. Y.
18. March 26-28, 1957 : Sixth Weather Radar Conference, M.I.T., Cambridge Massachusetts.
19. April 24-25-26, 1957 : Seventh Region I.R.E. Conference, San Diego, California.
20. May 22-23-24-25, 1957 : U.R.S.I. Spring Meeting, Washington, D. C.

B. — Fields within the horizon

Renewed interest has been taken in macroscopic tropospheric refraction. A number of methods have been developed for computing bending for refractive index profiles of arbitrary shape (42, 58). Second order corrections to account for systematic departures of the atmosphere from standard have been tabulated climatologically for thirty-four geographic locations. In the United States the day-to-day errors average ± two milliradians in winter and ± three milliradians in summer at an elevation angle of fifty milliradians, or about three degrees. Experimental observations (7) are in good agreement with computed bending.

The effect of micro-meteorology on optical fields has received some attention (106, 57, 157). Phase and amplitude measurements have been obtained over an optical link (52, 70, 71). The phase variations are larger than the associated amplitude variations, indicating that the dominant refractive index effects are perhaps still macroscopic.

Further work has been done on the effects produced by irregular surfaces. Advances have been made in the measurement of the roughness of the sea surface (43, 44). These results have been used in describing the radar return from the sea surface (79, 80, 160, 3). A phenomenological study has been made of the forward scattered radiation (22, 134). Recent studies of terrain effects have indicated that the foreground in front of the antenna may be of considerable importance (2, 30, 143). One paper dealing with terrain return at normal incidence has appeared (104).

C. — Fields beyond the horizon

The October 1955 issue of the *Proceedings of the Institute of Radio Engineers* contained papers summarizing the state of the art of tropospheric propagation to distances well beyond the horizon. A great deal of the experimental data were amalgamated into empirical transmission loss curves (23, 31, 32, 64, 109, 111, 119). By and large, the theoretical attempts to explain these long distance transmissions have been based on the postulated scattering mechanisms (27, 59, 60, 127, 129, 130, 147, 157, 128, 109, 111). A description in terms of normal mode theory has continued to receive some attention (35, 36). More recently

layer reflection has been revived as the possible mechanism producing transhorizon fields (16). One school of thought places the reflecting layers in the common volume (61), a second group maintains that the energy is reflected by the stronger layers occurring in the lowest region of the troposphere. For distances well beyond the horizon, multiple reflection is necessary, a fact which leads to considerable difficulty. Tractable solutions for the reflection process are still wanting.

Studies have been made of the effect of antenna size and beamwidth on power absorbed in the scattered field (26, 109, 131, 144, 12).

Methods have been evolved whereby the « obstacle-gain » phenomenon can be effectively utilized on non-optical communication links over mountainous terrain (49, 86, 88, 109).

Although theoretical attempts to link propagation with meteorological parameters have not been as successful as one would wish, work has been proceeding in utilizing empirical relationships in predicting propagation from routine meteorological data (18). A method has been developed (66) using controlled propagation data on a non-optical over-sea link for predicting non-optical fields in the diffraction region in the presence of elevated inversions.

The effects of the oceanic duct on microwave radar coverage have also been worked out, using routine shipboard meteorological data. A method for handling statistical data in making such predictions over large oceanic areas has been developed (8) and applied to areas in the Pacific and Indian Oceans.

D. — Radar weather

Radar weather developments up to about the time of the Eleventh General Assembly of U.R.S.I. have been previously reviewed (96, 112). Recent developments have been made in the study of precipitation of cumulus clouds (118) and of tornadoes and hail (69, 113, 132). Other topics include : Snow (9), The Bright Band (9, 154, 155), Meso-Scale Patterns (10, 24, 102, 93), Hurricanes (91, 82, 41), Cloud (53, 116, 155, 92), Angels and Lightning (40, 133, 93), Theory (78, 54), Shape and Depolarization (107), and Attenuation (53, 48, 69).

E. — Ground wave propagation

Recent interest in navigational systems has motivated detailed numerical computations of ground wave propagation at low radio frequencies over a homogeneous smooth earth. The propagation over stratified ground (150) and mixed paths has also been considered. The behavior of a pulse or transient signal propagating via the ground wave mode has been treated in some detail (149).

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Resolutions of U. S. A. Commission II

1. It is recommended by Commission II that :

(*a*) the extent of the dependence of scattered signals on latitude, climate and terrain should be further studied by means of observation in differing geographical areas.

(*b*) In particular, measurements of field strengths from high-power transmitters should be made at great distances and for various frequencies, antenna heights and gains. Use of aircraft in such measurements is recommended.

(*c*) Propagation studies should be extended to include investigation of pulse distortion, phase stability, fading rates, and diversity properties of the signal.

(*d*) Simultaneous meteorological measurements designed to improve understanding of the propagation mechanism are desirable.

(*e*) Quantative knowledge of the means of relating the above findings to practical radio results should be extended, especially in the direction of providing satisfactory approximations.

2. In view of the importance of conditions in the lower atmosphere to the propagation of the shorter radio waves, it is recommended that U.R.S.I. take steps to insure that national meteorological authorities are aware of the need of radio scientists for meteorological observations and that such observations should be organized so as to provide as much information as possible for application in the radio field. It is recommended that national meteorological authorities should be encouraged to :

(*a*) perform more detailed meteorological measurements, including those with airborne equipment, with emphasis on the study of the fine structure of the atmosphere. Special attention should be given to the detailed variation of the refractive index in the region where this index undergoes significant changes. The use of the refractometer for such measurements is strongly recommended.

(*b*) Complete meteorological data of the nature described under (*a*) for the purpose of using these data as a help in prediction, on a statistical basis, of the propagation characteristics to be expected in various geophysical regions.

3. It is recommended that, whenever possible, meteorological measurements of a sufficiently detailed character to throw light on the mechanism of propagation be carried out in conjunction with programs of propagation measurements. It is suggested that many varieties of atmospheric phenomena are directly or indirectly germane to tropospheric radio propagation; hence, multi-purpose meteorological and radio signal measuring programs are recommended as mutually beneficial and economic.

N° 302. — Addendum to Report of U.S. National Commission

Theoretical Research on Tropospheric Scatter Propagation in the United States 1954-1957, by Harold STARAS, Radio Corporation of America, Princeton, New-Jersey and Albert D. WHEELON, The Ramo-Wooldridge Corporation, Los Angeles, California.

1. — SUMMARY

Considerable theoretical progress in understanding tropospheric scatter propagation beyond the optical horizon was made in the three years just past. The problem may be broadly divided into : (1) characterization of the random medium ; (2) electromagnetic calculations of the average signal strength as a function of distance and frequency, and (3) estimations of the signal's statistical properties. An important shifting of emphasis from the space correlation to the spectrum of turbulent irregularities has taken place, and has provided a unique representation of time variations of the medium and signal. Physical theories of turbulent irregularities have been developed on the mixing-in-gradient hypothesis and are quite successful in explaining the radio frequency and distance dependence of the transmissions, as well as observed meteorological correlations.

Statistical descriptions of the received signal's fading envelope have been considerably improved. The distribution of amplitudes and variable frequency dependence of fading rates have been successfully predicted. Computations of space correlation for the field and height gain indicate that the scattering blobs may well be anisotropic. Antenna gain-degradation and beam-swinging experiments with very narrow beams seem to agree with theoretical estimations. Considerable attention has been directed to the bandwidth limitations of this propagation mode and to optimum modulation schemes.

A new approach to the problem based on reflection by one or more refractive layers has been proposed. Satisfactory agreement with average signal levels is provided by these theories, although the statistical properties remain to be studied. Normal mode theory based on partial internal reflections by a bilinear atmospheric profile model continues to play an offstage role for lack of specific results.

2. — Characterization of a Turbulent Medium

The tropospheric index of refraction varies from point-to-point in a random manner. To describe this effect, one decomposes the dielectric constant ($\varepsilon = n^2$) into its mean value and a small stochastic component.

$$\varepsilon(r, t) = \varepsilon_o + \Delta\varepsilon(r, t) \tag{2.1}$$

ε_o is considered to be a function of altitude (h) only and its gradient appears in several physical theories of turbulent irregularities. The function $\Delta\varepsilon(r, t)$ is usually treated as a stationary random process, which is spatially homogeneous and isotropic.

$$\begin{aligned} &<\Delta\varepsilon(\vec{r}, t)> = 0 \\ &<\Delta\varepsilon(\vec{r}, t)\Delta\varepsilon(\vec{r + R}, t)> = (<\Delta\varepsilon^2> C(|\vec{R}|) \end{aligned} \tag{2.2.}$$

Little attention has been paid to higher moments, except to note that they are completely specified in terms of $C(r)$ if the $\Delta\varepsilon$ form a Gaussian random process. The intensity of dielectric fluctuations $<\Delta\varepsilon^2>$ is measured experimentally as several parts in 10^{-12}, while the correlation function falls to $1/e$ in a distance of several hundred feet. It is often assumed that $<\Delta\varepsilon^2>$ decreases with altitude as h^{-m}.

The space correlation function C(R) is the fundamental characterization of the turbulence and its choice sets the radio frequency and distance dependence of scatter propagation theories. The exponential model $C(R) = \exp - R/l_o$ has been used extensively in the past, although the Bessel model $(CR) = (R/l_o)K_l(R/l_o)$ currently seems to give better agreement with experiment. Anisotropic irregularities can be discussed by introducing different scale lengths in orthogonal directions (1, 2) viz

$$C(R) = \exp - \left[\frac{x^2}{l_1^2} + \frac{y^2}{l_2^2} + \frac{z^2}{l_3^2}\right]^{1/2} \tag{2.3}$$

An equivalent characterization of a turbulent medium is the spectrum of irregularities (3), which is the Fourier decomposition of the space correlation functions.

$$<\Delta\varepsilon^2> C(R) = \frac{1}{8\pi^3}\int d^3k e^{-\vec{ik}.\vec{R}} S(k) \qquad (2.4)$$

If the medium is isotropic, $S(k)$ depends only on (k). The mean square fluctuation at a point,

$$<\Delta\varepsilon^2> = \frac{1}{2\pi^2}\int_0^\infty dk\ k^2 S(k) \qquad (2.5)$$

indicates that the spectrum represents the ability of each blob size group to produce irregularities.

Equation (2.4) may be inverted to compute the spectrum corresponding to a given correlation function. Table I indicates the spectra for the Gaussian, exponential, and Bessel models.

TABLE 1

C(R)	e^{-R^2/l_0^2}	e^{-R/l_0}	$\frac{R}{l_0} K_1\left(\frac{R}{l_0}\right)$
S(k)	$\pi^{3/2} <\Delta\varepsilon^2> l_0^3 e^{\frac{-k^2 l_0^2}{4}}$	$8\pi \frac{<\Delta\varepsilon^2> l_0^3}{[1 + k^2 l_0^2]^2}$	$6\pi^2 \frac{<\Delta\varepsilon^2> l_0^3}{[1 + k^2 l_0^2]^{5/2}}$

To describe the temporal behavior of electromagnetic instabilities, one must consider the generalization of (2.2) displaced in both time and space. Time variations of $\Delta\varepsilon$ are associated with two types of motion :

(*a*) *Drifting convection.* — The entire (frozen) structure is borne along on prevailing winds, and is equivalent to an additional space correlation distance $\vec{U}\tau$.

(*b*) *Random motion.* — If one rides along with the net flow, there is still motion associated with continuous eddy breakup.

The combination of these two effects is expressed most conveniently by the spectrum method (3, 4).

$$<\Delta\varepsilon(r, t)\Delta\varepsilon(r + R, t + \tau)> = \frac{1}{8\pi^3}\int d^3k\, S(k) e^{\vec{ik}.(\vec{R} + \vec{U\tau})} C(k.\tau) \qquad (2.6)$$

$C(k, \tau)$ describes the time autocorrelation of fluctuations within

a fixed wave number interval k. In the inertial subrange, dimensional arguments show the $C(k, \tau)$ should depend only on $v_o k_o^{1/3} k^{2/3} \tau$, although no functional dependence has yet been established.

The spectrum method makes direct contact with physical theories of turbulent irregularities. Such theories identify three distinct ranges of the spectrum shown in Figure 1: (1) input range $0 < k < k_o$; (2) inertial range $k_o < k < k_s$; and (3) dissipation range $k > k_s$. In the troposphere, $l_s = k_s^{-1}$ is of the order of millimeters and $l_o = k_o^{-1}$ is a hundred meters or more. Only the inertial range is of interest to tropospheric scatter, since aperture smoothing eliminates the contributions of small blobs in the dissipation range and the larger blobs are relatively inefficient scatterers. This is very important, since dimensional analysis can be used with some confidence in this range.

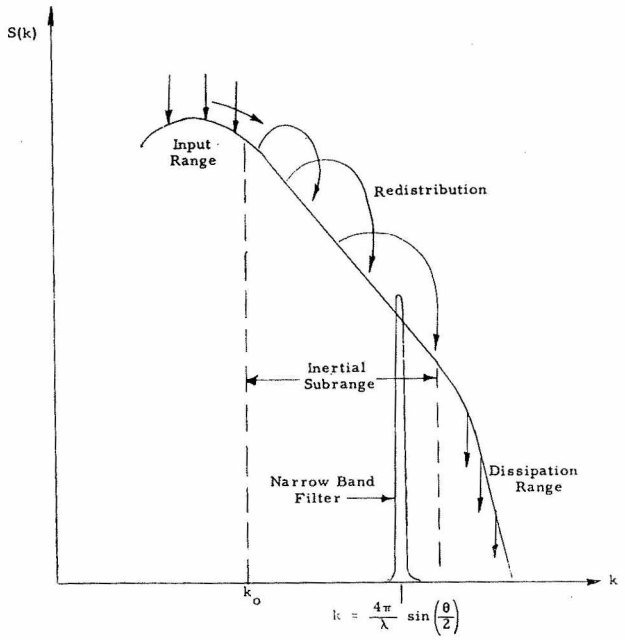


FIG. 1. — Typical Spectrum of Dielectric Irregularities Showing Ranges and Narrow Band Filter Which Characterizes Tropospheric Scattering.

Variations in the tropospheric dielectric constant are governed principally by water vapor content. One is dealing therefore with the irregularities established in a passive scalar by turbulent

movements of the atmosphere's (vector) velocity field. There are two popular theories which predict $S(k)$: (1).

1. — Obukhov's Mixing Theory

In this theory, an external source is imagined to feed fluctuations into the spectrum at the largest blob size (k_o). Subsequent redistribution down the inertial range is attributed to turbulent convection, for which dimensional arguments give (5, 6, 7).

$$S(k) = <\Delta\varepsilon^2> \frac{k_o^{2/3}}{k^{11/3}}, \quad (k > k_o) \tag{2.7}$$

If the external source is identified only with the mixing of a gradient by the largest blobs,

$$<\Delta\varepsilon^2> \backsimeq k_o^{-2} \left(\frac{d\varepsilon_o}{dh}\right)^2 \tag{2.7'}$$

2. — Mixing-in-Gradient Theory

In this approach one considers an initial refractive index gradient and how it is changed by turbulent convection. As the turbulent eddies rotate, they transfer parcels of water vapor from low to high points on the profile and vice versa. The mechanism for turbulent fluctuations appears explicitly in this theory, and no external source is required. The inertial range is again amenable to dimensional arguments (8, 9).

$$S(k) \backsimeq \left(\frac{d\varepsilon_o}{dh}\right)^2 \frac{1}{k^5}, \quad (k > k_o) \tag{2.8}$$

Both of these theories predict that the intensity of turbulent fluctuations is proportional to the gradient of the inhomogeneous mean profile. A very good correlation between the strength of scatter signals and refractive gradient has been observed experimentally on many paths (10). Since strong scattered signals are associated with large dielectric fluctuations, this must be

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(1) Most writers now agree that the pressure fluctuation mechanism is unimportant for the troposphere.

considered an important success for both mixing theories. They are compared in the next section as to their frequency and distance dependence predictions.

3. — Electromagnetic Scattering by Turbulence

In deriving the wave equation from Maxwell's equations for an inhomogeneous medium the electric vector is found to satisfy (11).

$$\nabla^2 \vec{E} - \frac{1}{c^2} \frac{\delta^2}{\delta t^2} (\varepsilon \vec{E}) = -\vec{\nabla} \left[\frac{1}{\varepsilon} \vec{E} \cdot \vec{\nabla} \varepsilon \right]. \tag{3.2}$$

For radio propagation through the atmosphere several approximations are possible. Time derivatives operate principally on $\vec{E}$, since the field oscillates much more rapidly than the medium. The right hand side of (3.2) is neglected (12) since $\frac{\nabla \varepsilon}{\varepsilon} << 1$, thus with a harmonic time dependence ($k = \omega/c = 2\pi/\lambda$), (3.2) reduces to

$$[\nabla^2 + k^2(\varepsilon_o + \Delta\varepsilon)] \vec{E} = 0 \tag{3.3}$$

The Born approximation is widely used as a solution of (3.3) and gives the total field in terms of the unperturbed wave $E_o(r)$ as

$$E(R) = E_o(R) - \frac{k^2}{4\pi} \int_V d^3r \frac{e^{-ik|\vec{R}-\vec{r}|}}{|\vec{R} - \vec{r}|} \Delta\varepsilon(r, t)\, E_o(r) \tag{3.4}$$

where V is the common volume of irregularities, which are both illuminated by $E_o(r)$ and visible to the receiver (R). The geometry for propagation beyond the horizon shown in Figure 2 indicates that the radiated wave $E_o(r) = E_o e^{i\vec{k}\vec{l}.\vec{r}}$ cannot reach the receiver because of earth-screening, so that the first term is dropped. Since the receiver is always many wavelengths from the scattering blobs, the far-field approximation is used.

$$\frac{Es(R}{E_o} \backsimeq \frac{e^{-ikR}}{4\pi R} k^2 \int_V d^3r e^{i\vec{K}\cdot\vec{r}} \Delta\varepsilon(r, t) \tag{3.5}$$

where $\vec{K} = \vec{k}_1 - \vec{k}_2$ is the scattering difference vector. The magnitude,

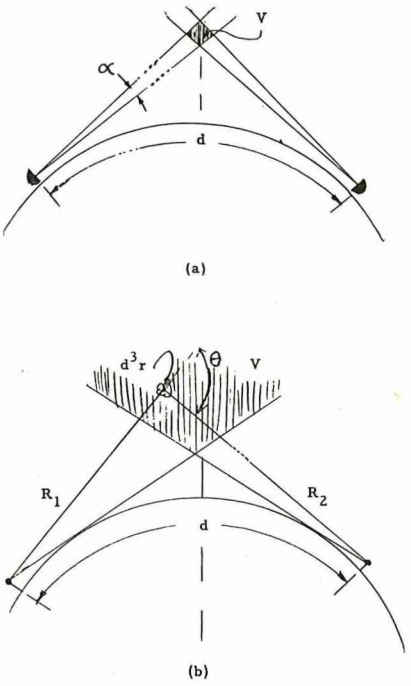


FIG. 2. — Geometry for Scatter-Propagation Calculations : (*a*) Narrow Beams and (*b*) Broad Beams.

$$\left|\vec{K}\right| = \frac{4\pi}{\lambda} \sin\frac{\theta}{2} \tag{3.6}$$

depends jointly on the wavelength of the radiation and the angle θ through which the scattering proceeds (see Figure 2).

The scattering cross section $\sigma(\theta, \lambda)$ per unit volume, per unit solid angle, and per unit incident power characterizes the scattering process for each blob.

$$\sigma = \frac{R^2}{V} < \left| \frac{E_s(R)}{E_o} \right|^2 > \tag{3.7}$$

When this is combined with (3.5) and (2.4), one is able to express the cross section directly in terms of the spectrum (1).

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(1) Also

$$\sigma = \frac{\pi^2}{\lambda^4} \int_V d^3r \; e^{i\vec{K}\cdot\vec{R}} < \Delta\varepsilon^2 > C(R)$$

$$\sigma(\theta, \lambda) = \frac{\pi^2}{\lambda^4} S\left[\frac{4\pi}{\lambda} \sin\frac{\theta}{2}\right] \tag{3.8}$$

The scattering process acts like a narrow-band filter on the spectrum shown in Figure 1, emphasizing the wave number $k = (\vec{K})$ (see 3.6). Experimental combinations of λ and θ focus attention on the inertial range of $S(k)$. The angular dependence of σ is often interpreted as the scattering polar diagram of an average blob. Reference to Table 1 shows that almost all of the scattered radiation is projected into a cone of angular opening λ/l_0 about the forward direction.

It has been suggested by Feshbach (13) that multiple-scattering is more efficient than one large-angle scattering. Such effects are certainly more important at higher frequencies, since the convergence of the Born series is related to the smallness of the equivalent line-of-sight mean square phase shift

$$<\alpha^2> = \pi^2 <\Delta\varepsilon^2> L l_o/\lambda^2 \tag{3.9}$$

computed along the ray path. It is hoped that further research will be directed to this interesting point.

4. — Frequency and Distance Dependence

The ratio of received-to-transmitted power depends upon the integral of the scattering cross section over the common volume V defined by the aerial patterns and/or earth screening. If G_1 and G_2 are antenna gains appropriate to beams which meet at the scattering point d^3r,

$$\frac{P_R}{P_T} = \frac{\lambda^2}{16\pi^2} \int_V d^3r \frac{2G_1\, 2G_2\, \sigma\ (\theta,\ \lambda)}{R_1^2\, R_2^2} \tag{4.1}$$

where R_1 and R_2 are identified in Figure 2. The factors of two represent the ideal smooth earth ground reflection factors and are only approximately correct. If the beams are so narrow that the scattering angle (and hence the cross section) is substantially constant over the common volume, the integration can be collapsed.

$$\frac{P_R}{P_T} = \frac{2G_1}{4\pi[d/2]^2} \sigma V \frac{\lambda^2\ 2G_2}{4\pi[d/2]^2} \tag{4.2}$$

The scattering volume is set by the antenna beam widths (α) and transmission distance (d) : $V \backsimeq 2\ (\alpha d/4)^3/\theta$ where $\theta \backsimeq d/a$. The mixing-in-gradient model (2.8) can be combined with this expression to predict

$$\frac{P_R}{P_T}\left(\frac{d\varepsilon_0}{dh}\right)^2 \alpha^3\ \lambda^3\ \frac{a^6}{d^7} \tag{4.3}$$

Such results are quickly established for other spectral models, and it would be well to compare their predictions with the considerable body of narrow beam data obtained by the M.I.T. Lincoln Laboratory.

The majority of broad beam data is expressed with respect to the free space power which would be received over a line-of-sight path of the same length (1).

$$\frac{P_R}{P_{F.S.}} = \frac{4\pi^2 d^2}{\lambda^4}\int_v d^3r\ \frac{S\left[\frac{4\pi}{\lambda}\sin\frac{\theta}{2}\right]}{R_1^2\ R_2^2} \tag{4.4}$$

The average patterns of the broad aerials are removed here to cancel the total gains. It is this integral which has occupied the time and efforts of so many workers. The problem is partially one of finding a judicious coordinate system in which to do the integrations over the common volume, as limited by earth screening. The NBS group (14) found such a system and made numerous calculations with the exponential correlation model. Waterman (15) has recently shown that (almost) any spectral model can be integrated exactly in this same coordinate system. Staras (1) developed a rectangular system to perform the same integrations in an approximate manner ; his system has the advantage of recognizing the height-dependence of $<\Delta\varepsilon^2>$ in a simple way and in being able to evaluate the space correlation and height gain functions.

In performing the volume integrations, one must eventually recognize a sizable number of refinements to the spherical earth model. The influence of irregular terrain in modifying the takeoff angles lead Norton et al (16) to the concept of (effective) angular

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(1) $\dfrac{P_{F.S}}{P_T} = \dfrac{G_1}{4\pi d^2}\dfrac{\lambda^2 G_2}{4\pi}$

distance. Refraction of the upgoing and scattered beams by troposphere has been described (16) so far by the usual (4/3) earth modifications of the spherical earth results. Bean (17) considered the influence of atmospheric absorption on the same beams and predicted the radio frequency and distance dependence, as well as the expected correlation with meteorological conditions. The question of scattering by diffracted waves in the shadow region (below the common volume) has been studied by Arons (18) who finds that the contributions are very small indeed. The inclusion of ground reflection factors and the inefficiency of ordinary height-gain relations is only partially complete. Anisotropic corrections to the scattering also may need to be included (1, 2).

Insofar as the inertial range alone is of importance to the integrations in Equation (4. 4), one may expect the frequency and distance dependence to split apart. The mixing-in-gradient model (2. 8) predicts a linear wavelength dependence (8, 9), which has been deduced experimentally by careful analysis of numerous broad beam experiments (17, 18, 19). It would appear that the $\lambda^{-1/3}$ dependence predicted by the Obukhov Model (2. 7) is not consistent with present radio data. The distance dependence of (4. 4) depends upon careful integration of the spectrum's angular dependence over the common volume. The NBS Group (14) first pointed out the need for assuming the intensity decreases with height in order to supply the additional inverse powers of distance required to reach agreement with experiment. The mixing-in-gradient model has no adjustable turbulence constants to influence this distance dependence, but does depend on the mean profile $\varepsilon_o(h)$. Estimations of this integral up to stratospheric heights using an exponential variation of $d\varepsilon_o/dh$ predict the range dependence of scattered fields quite well out to 700 miles (21).

5. — Statistical Properties of the Fading Envelope

The envelope of radio-frequency signals received beyond the horizon is found experimentally to be a random function of time and is Rayleigh-distributed. This is successfully explained by noting that both the real and imaginary parts of the scattered wave in Eq. (3. 2) are Gaussian-distributed, if $\Delta\varepsilon$ is itself a Gaussian normal random process. The magnitude of the vector sum of

two such components with equal variances is known to be Rayleigh-distributed (22, 23). A more general proof which does not rely on the Born approximation applies the Central Limit Theorem to the independent scattering contributions by many blobs in the scattering volume (24).

Time variations of the signal envelope are physically related to the random addition of doppler-shifted waves received from different elements of the scattering volume. The drift (U) and random (V_0) velocities of the eddies impose these frequency shifts on the scattered waves. The basic problem is to predict the radio-frequency and scattering-angle dependence of this fading, and the average rate of fading is taken as a convenient measure of the time-varying envelope. Early studies of this problem (20, 25) considered only the rms sum of these velocities as the effective speed.

$$N \cong \frac{f}{c}\left\{\left[2U \sin\left(\frac{\bar{\theta}}{2}\right)\right]^2 + \frac{1}{3}V_0^2\right\}^{1/2} \tag{5.1}$$

$\bar{\theta}$ is the average scattering angle in the common volume.

A considerable advance was made recently in analyzing this fading phenomenon by using the spectral representation of the turbulent dielectric fluctuations (26). An explicit separation of drift and random velocity contribution to the space-time correlation of $\Delta\varepsilon$ is given by Eq. (2. 6). Narrow-beam transmission is simplest to analyze, for the scattering angle is then substantially constant over the scattering volume. Since the scattered field is proportional to the Fourier transform of $\Delta\varepsilon(r, t)$, the time correlation of the field [1] becomes

$$\rho(\tau) = \frac{\langle E_s(t)E_s^*(t+\tau)\rangle}{\langle E_s(t)E_s^*(t)\rangle} = e^{i\vec{K}\cdot\vec{U}\tau}\, \dot{C}[V_o k_o^{1/3}\, K^{2/3}\tau] \tag{5.2}$$

where $\vec{K}$ is the scattering difference vector defined earlier. For symmetrical scattering, $\vec{K}$ points upward and only the vertical component of the mean wind contributes to doppler fading.

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[1] The envelope (linearly detected) correlation is related to the amplitude correlation by the standard result (22) :

$$A(t) = \frac{\langle |E_s(t)|\cdot|E_s(t+\tau)|\rangle}{\langle |E_s^2|\rangle} \cong \frac{\pi}{2}\left(1 + \frac{1}{4}\rho^2(\tau) + \frac{1}{64}\rho^4(\tau) \ldots\right) \tag{5.1'}$$

The self-motion influences the fading rate most strongly, if U_z is small,

$$\therefore \quad N \cong \frac{1}{\pi} \sqrt{-\frac{d^2\rho}{d\tau^2}\Big|_{\tau=0}} = \frac{V_o k_o^{1/3}}{\pi} \ddot{C}(0) \cdot \left\{ 2 \frac{f}{c} \sin \frac{\bar{\theta}}{2} \right\}^{2/3} \qquad (5.3)$$

where N is the average rate of mean crossings. The fading rate due to self-motion is proportional to $f^{2/3}$, while drift motion gives the usual doppler linear dependence on frequency. Available data indicates a variable frequency exponent less than one (27), so that some mixture of the two effects is indicated. For symmetrical scattering, only the self-motion effect is distance (θ)dependent. The problem should be reconsidered by integrating the above result (5. 2) over the large scattering volumes appropriate to the present broad beam data.

In addition to the fast fading described above, there is a long term variability of the mean signal level which is sometimes called « slow fading ». This variability is presumably caused by gross changes in meteorological conditions. There is a reasonable difference between monthly mean signal levels and averaged meteorological measurements (10) ; but day-by-day or (especially) hour-by-hour correlations have not been established. The prominent characteristics of this slow fading are :

(1) Average signal levels are ten db higher in summer than in winter.

(2) Longer scatter paths exhibit less variability over a given year than short paths, since the corresponding scatter heights are greater and there is less meteorological variability at the higher altitudes.

6. — Space Correlation of the Field

A combination of two or more spaced receivers is frequently exploited to overcome signal loss during deep fades. This diversity reception depends upon spacing the antennas sufficiently far apart to insure independent fading of the two signals. Staras (28) has solved the statistical problem of estimating the percentage of time that the *greater* of the two signals is below a specified level as a function of the correlation between the two fields.

The propagation problem is to estimate this space correlation. Gordon (20) and Rice (25) presented qualitative analysis which showed that correlation distances normal to the propagation path (horizontal and vertical) ought to be of the order $\lambda a/d$, where d is the transmission distance and a the radius of the earth. The correlation distance $\lambda a^2/d^2$ along the path was also deduced. Precise calculations of all three correlations as functions of the separation were presented by Staras (1), using the exponential correlation model and an h^{-2} dependence for the intensity of turbulence. The integrations were carried out for the entire common volume, so as to make contact with the broad beam data. To reach agreement with this data, he found it necessary to recognize the anisotropic nature of the scattering blobs (c. f. Equation (2. 3)) and deduced a vertical-to-horizontal scale length ratio of approximately one third. Such experiments are important in that they bear directly on the question of anisotropy and more data is needed. It would be valuable to repeat such calculations for the two mixing models, to see what effect the spectrum has on the predictions.

The realization of plane-earth height-gain advantages is limited by space coherence between the actual receiver and its image. The usual height-gain curve is measured at heights less than one-half the vertical correlation distance ($\lambda a/2d$). Above this height, one gains only slight improvement by the gradual decrease of the scattering angle. Detailed calculations of this effect (with differing approximations) have been presented by Staras (1) and the NBS group (29, 16, 19). Agreement between theory and experiment on this point is probably acceptable.

7. — Gain Loss and Beam Swinging

When very narrow beams are used on scatter circuits, it is found that free-space antenna gains are not realized. This has come to be known as gain loss or antenna-to-medium coupling loss. The coupling loss phenomenon arises from the fact that signals arrive at the receiver from an extended scattering volume V. Narrowing the antenna beam (α) eventually reduces this common volume faster than the aerial gain is increased (see Eq. 4. 2).

This problem was first qualitatively analyzed by Booker and de Bettencourt (30), and later generalized by Norton, Rice and

Vogler (16) and by Staras (31) to include nonsymmetrical antenna patterns and dissimilar aerial sizes. Staras evaluated the effect of anisotropic irregularities on the coupling loss. It would appear that the refined estimates of Norton, et. al. (16) and Staras (31) are in somewhat better agreement with the experimental data.

Booker and de Bettencourt (30) also considered the effect of swinging the transmitting and receiving aerials simultaneously in azimuth and elevation. In either case, the net effect is to increase the scattering angle and therefore to decrease the received power. They used the exponential correlation model to make estimates of this reduction which are apparently in good agreement with available data.

8. — Bandwidth Limitations

The signal-frequency bandwidth which the scatter medium can support without serious distortion is intimately related to the multipath delays which are experienced. These depend on the size of the effective scatter volume, which is determined by the antenna beamwidths and/or the scattering pattern of the blobs. When the antenna patterns are broad, the multipath is controlled by the scattering blobs and the approximate result

$$\Delta f = \frac{5ca^2}{d^3} \qquad \alpha >> \bar{\theta} \tag{8.1}$$

given by Gordon (20) shows that the bandwidth decreases rapidly with distance. Staras (1) computed the actual frequency correlation of signals at different frequencies for the anisotropic exponential correlation function. His results for the effective bandwidth are only one-eighth that predicted by Gordon ; however, he did not include the effect of diversity which is almost certainly going to increase the effective bandwitdh. This problem needs further resolution with experiment.

A real improvement in bandwidth capabilities is obtained with very narrow beams. Even though some antenna gain degradation is experienced with narrow beams, the angular distribution of multipath signals which are admitted to the receiver is reduced and the bandwidth thereby increased. Booker and de Bettencourt

(30) examined this problem for beams narrower than the average scattering angle $\theta = d/a$ and found

$$\Delta f = \frac{4ca}{\alpha d^2} \qquad \alpha << \bar{\theta} \tag{8.2}$$

which increases steadily with antenna size and less rapidly with distance. When aircraft fly through the path, the solid bistatic reflections from them supply a multipath signal of unusual magnitude and the above estimates for broad antenna beams are meaningless.

The influence of medium bandwidth on transmission quality depends upon the instantaneous signal level in the band, and this in turn has given rise to the concept of an instantaneous bandwidth. It is not clear now whether the bandwidth limitation refers to the base band or *r-f* band of an FM system, for instance, and considerably more work on modulation schemes is required. It is probable, however, that a double side band modulation scheme is preferable to SSB because it automatically provides frequency diversity when synchronous detection is used.

9. — Reflection by Elevated Layers

Layers are frequently observed in the troposphere as discontinuities in the vertical profile of refractive index measurements. It was suggested long ago that partial reflections from these layers might explain scatter propagation (36). Friis, Crawford, and Hogg (32) have developed this idea in some detail, using uncorrelated reflections from many layer patches in the common volume. These results depend on the size and number of layers, as well as the average refractive discontinuity across the sheets. The ratio P_R/P_{FS} (see Part 4) computed from this theory is proportional to the wavelength, in good agreement with experiment. Their predictions of beam swinging experiments and gain loss are also consistent with experiment. No explanation of fading phenomenon or bandwidth limitations has been given thus far, although it is probable that such effects can be accommodated by modulating the orientation of layers. The distinction between such layers and elongated blobs (i. e. anisotropic irregularities) however, is not sufficiently clear.

Bauer (33) has studied the partial reflections from a single spherical layer above the earth. There is some question about his use of the Born approximation to represent coherent reflections by the layer. His experimental correlation of scatter signal strengths with the refractive change across elevated layers in the path is certainly interesting.

It is likely that such layers are the seat of intense irregularities, if one believes the mixing models (2. 7) or (2. 8). The presence of such irregularities at the point of partial reflection would provide the layer theories with an additional random component to explain fading . The problem may be looked at differently, however, by saying that turbulent blobs are probably created most strongly at layer discontinuities, so that the important scattering volume is near the layer. Gordon (20) has studied the scattering by elevated turbulent layers briefly.

10. — Normal Mode Theory

The explanation of radio propagation beyond line-of-sight in terms of coherent partial reflections from a bilinear refractive index profile has been pursued by Carroll and Ring (34). Unfortunately, recent work on this theory is characterized more by stratagems than new results. Two important predictions of normal mode theory emerged from a symposium on this subject (35). The received field strength : (1) varies exponentially with distance and (2) is independent of radio frequency. The first prediction agrees best with experiments, in which it is difficult to distinguish between an exponential variation and a large inverse power of the distance.

The discontinuity in the bilinear profile model of refractive index is of continuing concern to Friedman and others (35). Although coherent reflections from stable layers may contribute to the mean signal, normal mode theory offers no explanation of the following important features of scatter propagation : (1) fading envelope, (2) bandwidth limitations, (3) space correlations, and (4) gain loss effects. Unless these results can emerge from the series representation of the field employed (at least) one must superimpose a statistical variation of the dielectric constant upon the Carroll model.

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Report on the Work of Commission II

to the Plenary Opening Session

by R. L. SMITH-ROSE, *Chairman of the Commission*

The activities of Commission II have been continued and extended since the XIth Plenary Assembly : and many investigations are in progress with the object of attaining a better and more complete understanding of the effect of meteorological conditions on the propagation of radio waves. It is gratifying to note the contributions now being made to this work by national committees who have recently become members of the Union.

Although the title of Commission II has for simplicity been defined as « On Radio and Troposphere », the field of activity of the commission includes the study of the effects of the terrain, its irregularities in profile and variations of electrical characteristics on the propagation of radio waves of all frequencies above about 30 Megacycles per second.

It is in fact always wise to consider the effects of the ground as well as those of the troposphere in research on the propagation of waves at such high frequencies. Within the horizon distance sudden changes of conductivity of the earth's surface — such as occur at the transition from land to sea — may affect the radio field strength. Beyond the horizon, the propagation may not be so dependent on the electrical characteristics of the ground, but it is still necessary to consider the diffraction of waves over the peaks of hills and mountains in relation to the refractive effects of the atmosphere. Indeed, it has been demonstrated that under certain conditions, the field strength of the waves beyond an obstacle such as a hill may be stronger than it would be within the horizon distance— or if the hill were not there. This is now termed the well-known « obstacle-gain » effect.

For the present General Assembly some 50 papers have been submitted including 13 or more reports from national committees ; all these demonstrate the wide range of attention that is being given to this subject in various parts of the world.

It is now well established that the vertical gradient of refractive index resulting from the lapse of temperature and humidity in the atmosphere can markedly influence the propagation of very short radio waves. In a stable atmosphere, this change of vertical gradient may occur sharply at certain levels at which well defined reflecting layers are formed. On occasion the conditions may result in the formation of a duct, which need not necessarily be at ground level, but which effectively traps most of the energy of the waves, which are thus transmitted to distances beyond the horizon range.

It has further become apparent in recent years that, for more turbulent atmospheric conditions, the field strength of short radio waves at distances well beyond the horizon is greater than can be accounted for on the basis of refraction or reflection effects. Various theories have been advanced suggesting that these fields beyond the horizon may be due to scattering of the waves by localised discontinuities in the atmosphere. The theoretical investigations have been stimulated very much by the practical demonstration of the use of the scattered fields for communications purposes. The papers which are before the commission for the present assembly indicate the rapid increase of our knowledge of this subject. But owing to the many variables and their unpredictable nature, it is necessary to adopt a statistical approach in their investigation. The work is conducted in close collaboration with the meteorologists for whom the radio scientist has provided a powerful new instrument in the form of a microwave refractometer. With the aid of this, the refractive index and its gradient may be measured at various heights in the troposphere.

Since the General Assembly at the Hague in 1954, a successful symposium was held in Paris in 1956, at which discussion of the progress of research in tropospheric wave propagation formed part of the programme. Mention should also be made of the interest of C.C.I.R. in the work of U.R.S.I. in this field. At the meeting of C.C.I.R. in Warsaw in 1956, Study Group V, of which I have the honour to be chairman, set up a working group to revise the

previously existing propagation curves at very high frequencies ; this group is continuing its work here in Boulder with the aid of the scientific results which arise from the work of our commission.

To sum up — at the sessions planned for Commission II, there in Boulder we shall consider the phenomena associated with the transmission of very short radio waves, first to distances within the horizon — or line of sight — and then to greater distances.

We shall endeavour to relate the radio phenomena observed to the corresponding meteorological conditions, and discuss the various theories put forward to explain the refraction, reflection — and particularly the scattering of radio waves in the lower regions of our atmosphere.

Minutes of Technical Sessions

Technical Session I : Wednesday, August 28, 1957, 09.30

Subject : *Tropospheric Propagation Wilhin the Horizon.*

Attendance : 50-60.

Representatives were present of 12 of the 24 countries which are official members of Commission II (Canada, Czechoslovakia, France, Germany, Great Britain, Italy, Japan, Netherlands, Sweden, Switzerland, U. S. S. R. and U. S. A.). SAXTON introduced the topic « Irregular Terrain and Mixed Path Propagation at Frequencies Above 30 Mc/s ».JOSEPHSON presented Doc. 174. TROLESE described 3300 Mc/s experiments in the Arizona desert dealing with path profile effects both under normal and super-refractive meteorological conditions. Discussion followed by AMENT, NORTON and KATZIN. Doc. 84 was presented by title « Inhomogeneous Path and General Features of Ground Wave Propagation », by E. L. FEINBERG. STRAITON summarized Doc.144 concerning reflection of 9 cm, 3.2 cm, and 8 mm waves from a wind-rippled lake. Discussion followed by GHERZI, HERBSTREIT, KATZIN, EKLUND, KIRBY, WHEELON and CHISHOLM. BECKMANN next presented the essence of a paper on theory of reflection from rough surfaces (See Doc. 82, Com. VI) (Acta Technica C.S.A.V., vol. II, n° 4, 1957). The paper was discussed by WATERMAN, CHISHOLM, STARAS, AMENT, STRAITON, NORTON, KATZIN and TWERSKY, and closed with BECKMANN's observation that while theoreticians sometimes start with assumptions not rigorously true, sometimes they start out very rigorously, but add non-rigorous approximations along the way in the course of development.

SMYTH introduced the second topic of the session « Effects of the Troposphere on Propagation ». NAITO summarized IKEGAMI's Doc. 18 on Ray Theory Analysis of Fading due to Atmospheric Ducts. Doc. 120 was mentioned by title only, since no one from

Italy was available to present if. ANDERSON summarized Doc. nº 111 on comparison of measured and computed refractive bending in the troposphere, and discussion followed by WONG, MARSHALL, KLINE and NORTON. BEAN then amplified Doc. 246, with discussion following by WONG, ANDERSON, EKLUND, SMYTH and NORTON.

Technical Session 2 : Thursday, August 29, 1957, 14.00

Subject : *Tropospheric Propagation Beyond the Horizon* (excluding tropospheric scattering).

1. — *Obstacle Gain Phenomena.*

R. S. KIRBY introduced this subject by remarking on its immediate practical importance in mountain areas. He then described the results of observations on frequencies 60, 192, 1000 Mc/s for which Pikes Peak served as the obstacle. Discussion followed by ROCHE, FINE, CHISHOLM, GHERZI, BULLINGTON, SAXTON, GERKS and CARROLL. Next, KANO and NAITO presented observations of diffraction over Mt. Fugi on 3000 Mc/s, with narrow and broad beamed antennas. Participants in discussion were RICE, CHISHOLM, SMYTH, BULLINGTON, HERBSTREIT, WATERMAN, TROLESE, NORTON,SMITH-ROSE and KATZIN. GROSSKOPF described television reception from Italy in the Black Forest over a 350 km path crossing the Alps. GERBER enlarged on some remarks in Doc. 140 (Report of the Swiss National Committee) concerning barrier-gain by the Alps for television on metric wavelengths. He stressed the stability and acceptable quality of the pictures, and expressed the opinion that revision of the Stockholm plan must consider the phenomenon. ALLEN remarked that television of quality suitable for rebroadcast was received at Harrisonburg, Virginia, about 110 miles from Washington over an intervening ridge. It was reported by a member of the Japanese delegation that one Japanese television station 200 km from Tokyo relied on the stability and quality of pictures received by the obstacle gain mechanism. BACHYNSKI described theoretical and experimental work on 24 Kc/s model experiments for diffraction over a cylindrical obstacle.

2. — *Reflection and Refraction Effects.*

BECKMANN introduced the subject of reflection effects by classifying three types of reflection theories for sharp, smoothly graded and irregular layers. While both layer reflection (coherent scattering) theories and turbulent scattering theories seemed to give correct frequency and distance dependence, he believed that day-to-day variations and KLINKER's metre wave experiments in Germany favoured the layer reflection hypothesis (Nachrichtentechnik, vol. 5, May 1957, pp. 210-215). He suggested that the layer theories appeared more logical and important than the turbulent scattering theories. EKLUND presented Document 175, concerning field strength measurements over an obstructed 30 km path on 2300 Mc/s and their correlation with varying meteorological conditions. A discussion on terminology was initiated by SAXTON, who deplored the implied limitation by some speakers of the term « scattering » to the incoherent type as used in turbulent scattering theories. The contrast between incoherent scattering from blobs or raindrops, and the coherent scattering or reflection from layers was elaborated. GORDON said that large index gradients associated with layers could lead to increased turbulence. CRAIN objected that the mixing-in-gradient hypothesis was wrong when applied to West Coast of the U. S. A. layers. STRAITON amplified the portion of Doc. 244 relating to the behaviour of mm waves in low level ducts, and the additional attenuation suffered by mm waves as compared to cm waves because of absorption, irregularity of meteorological profiles, and surface roughness. ROGERS described the 220 Mc/s experiments abstracted in Doc. 250, concerning over water airplane observations extending to distances of 1000 km and to heights of 40.000 feet. The highest flights were at least 5000 feet above the tropopause, and the results could not, therefore, be interpreted in terms of reflection from that level. CRAIN asserted that Wright Field refractometer data in the tropopause region showed small uninteresting index changes. NORTON asserted that BOOKER-GORDON turbulence theory assumed little contribution from the tropopause levels. CHISHOLM described experiments extending to 700 miles, in which the common volume passed through the tropopause without enhancement of the received scatter fields.

Further discussion ensued on the theoretical implications of

observed lack of difference between fields observed on the ground and at 20 000 feet. BECKMANN showed a photograph of a patchy cloud field indicative of horizontal stratifications and their influence on observed reflected fields. CHISHOLM concluded the session with a description of moisture fine structure contours measured over New England by airborne refractometer and aerograph observations.

Technical Session 3 : Friday, August 30, 1957, 14.00

Subject : *Scattering in the Troposphere* (Experimental).

Attendance : Average 70.

CHISHOLM introduced the subject by noting that tropospheric propagation well beyond the horizon was partly an outgrowth of the development of high power transmitters during the war, and that such propagation could be observed at frequencies as low as 15 Mc/s and lower. He remarked that theories should strive to explain not only the existence of the field, but also the frequency dependence, attenuation rate, variability of signal level, antenna gain realization, useful bandwidth, and optimum modulation methods. GROSSKOPF described experiments over a 226 km path on 91 Mc/s, for determining the height dependence of the field strength and the deformation of the antenna pattern (Doc. 117). SAXTON summarized Doc. 152 and showed typical records of tropospheric scatter signals on 53.25 and 1370 Mc/s. He expressed the view that the field strength records were not necessarily to be interpreted as scattering from turbulence, but perhaps were indicative of reflections from a few elevated layers, even if such were not detectable by routine radio-sonde ascents. A photograph of a 10 cm vertical radar sounding showing layer-like echoes from 3 km height provoked discussion by CHISHOLM, AMENT, GHERZI, SIMON, CARROLL, SMYTH and ANDERSON. GHERZI described reception of 200 Mc/s signals over a 300 km path near Hong Kong, which were indicative of stable reflecting layers. SMITH-ROSE drew attention to Figures 1 and 3 of Doc. 232 from Poland, with CHISHOLM and BULLINGTON agreeing that the low antenna heights used in these measurements might account for some of the differences from BULLINGTON's data.

JOSEPHSON next presented Doc. 176 on « Distance Dependence,

Fading Characteristics, and Pulse Distortion of 3000 Mc/s Trans-Horizon Signals ».

Discussion principally by AMENT and GORDON brought out the point that the distance dependence of field strength in the scatter region, presuming the common-volume idea, is intimately connected with the assumptions made about height dependence of the scattering parameter. GORDON said that frequency comparison experiments should always be done with identical scaled beams, in order that frequency and height dependence of the scattering parameter should not be confused. KATZIN made a plea that future experiments be multi-frequency, in order to reduce the number of arbitrary parameters available for theoretical explanations. BULLINGTON commented that fading and pulse break-up should not be misinterpreted to mean serious bandwidth limitations. He described the gradual increase of voice channel capacity in recent years on scatter circuits, and announced that television transmissions had recently been observed over a 300 km path between Florida and Cuba, with a frequency of 800 Mc/s and paraboloidal aerials 60 feet in diameter. The pictures were stable, without long multipath delays, and of quality better than the films now widely broadcast. He said it required much persuasiveness to encourage the expenditures for these tests, in the face of many pessimistic theoretical predictions about multipath scatter propagation.

WATERMAN amplified his unnumbered Document « Observations of Antenna-Beam Distortion in Trans-Horizon Propagation » (published in Transactions of the I.R.E. Professional Group on Antennas and Propagation, July 1957). The experiments were made in California, and seemed to indicate something less than an inverse fourth power law of decay with distance. CHISHOLM presented experimental data on frequency and distance dependence of scattered fields ; scaled beam experiments, at 417 and 2290 Mc/s ; time delays and pulse broadening of 1/4 μ second pulses with synchronously swung 3670 Mc/s aerials ; frequency sweep experiments designed to show the instantaneous bandwith of the medium ; frequency sweep experiments on an airplane echo ; beam swinging over a 350 mile path ; antenna gain realization on 2290 Mc/s for both equal and unequal antenna beams. GORDON suggested that the failure of some of CHISHOLM's pulse delay

times to agree with that calculated for a common volume defined by the main lobes, may perhaps be due to side lobes giving rise to additional common volumes. In rebuttal, CHISHOLM cited certain Bell Laboratories' broad-to-narrow beam observations, and 600 mile observations tending to show little contribution to the field from angles of elevation appreciably above horizontal.

AMENT enlarged on the abstract of Doc. 249 describing experiments at 1260 Mc/s over a 263 nautical mile path between Florida and the Bahamas. He also mentioned a common type of « rabbit-ears » pulse distortion which seemed indicative of two-path propagation, which was especially noticed when a thunderstorm was along the path. In discussion, CHISHOLM recalled reflections from lightning trails at 410 Mc/s at Lincoln Laboratory, and at 1000 Mc/s by Collins' workers. GORDON emphasized the importance of mean wind as well as turbulent wind in interpreting fading rates. Chisholm mentioned that a 60-foot dish and a coaxial broad beamed receiving antenna had essentially synchronous fading on fields transmitted from a 60-feet dish over a 618 mile path on 417 Mc/s. WHEELON inquired about fading rate and fading range on scaled antennas as a function of distance, and CHISHOLM replied that little change was noted from 300 to 600 miles. ROCHE described preliminary measurements of 8/1 ratio of fading rates of 2290 and 417 Mc/s signals received over a 188 mile path using antennas scaled to have equal beam widths, as deduced from 20 one-minute simultaneous samples during a typical 24 hours period. BARSIS recalled fading rate comparisons for various broad-beam antennas published in the 1954 I.R.E. convention record. The topic of scattering theory was deferred to Session 6.

Technical Session 4 : Monday, September 2, 1957, 09.30

Subject : *Radio and Meteorology.*

Attendance : (average) 45.

HERBSTREIT summarized and amplified the unnumbered document « Radio Studies of Atmospheric Turbulence on Line-of-Sight Paths », by HERBSTREIT and THOMPSON, giving the energy density spectrum as deduced from phase fluctuation measurements on a single optical path from Mt. Haleakala, Hawaii, on 9414 Mc/s. NORTON described a modification of turbulence theory based on a

Bessel autocorrelation function, using different scale lengths parallel to the wind and at right angles thereto. GORDON inquired about the high end of the spectrum, and about the effects on the frequency law of using a different autocorrelation function. NORTON added that unremoved trends tended to flatten the slope of the tail of the spectrum, but that possibly the flattening described a real atmospheric effect. SMYTH inquired about measurements of amplitude fluctuations on line-of-sight paths, and their comparison with theory. NORTON replied that such data were available, but had not been compared with theory, which has not yet been worked out; further, that this was a second order effect compared to the first order effect of phase fluctuations. CRAIN objected that his experience had shown that the problem was very complex and variable from day-to-day, and that no one correlation function or spectrum could fit the variety of data obtained. NORTON replied he believed the Bessel correlation function always true in the similarity range, and that new phase fluctuation results on 10 000 Mc/s were more sensitive than older measurements on 1000 Mc/s, which showed an f^{-2} spectrum because no band pass filter was used and trends were present. MARSHALL brought out the height variation over the Hawaii path. GORDON criticized the flattening of the spectrum tail. NORTON discussed the possibility that this was a real effect, or perhaps a reading error resulting from the digital analysis used for the magnetic tape method of getting the spectrum. CARROLL pointed out that the Bessel correlation function used had an infinite second derivative at the origin, which implied, by the Taylor-Richardson theorem (1922), infinite mean square density gradient and energy loss.

LANGILLE described some recent 500 Mc/s observations over a 85 mile path in Canada which showed as much as a ten-fold increase of the fading rate associated with the passage of fronts over the path. He hoped this might perhaps become a meteorological tool to detect passage of weak fronts. A discussion ensued of the synoptic weather in Hawaii by AMENT and HERBSTREIT. MISME remarked that the study of wind distribution around a mountain had been known for many years (1937), and that it was necessary to be cautious in applying classical theories of aerodynamics. There had been important divergences between theory and experiment during a study around the mountainous island

of FOGO in the South Atlantic. FANNIN amplified Documents 243 and 244, concerning attenuation and backscattering of mm waves due to natural rain, and water drops of controlled size; studies of index of refraction contours at the surface and aloft and their relation to the meso-meteorological situation; and refractometer-measured profiles in a variety of different locations (Ohio, Pacific Coast, Florida).

SAXTON, CRAIN and JOSEPHSON discussed the temperature compensation of refractometer cavities, and the interpretation of airborne sounding records. BEAN amplified the abstract of Document 247 concerning relation of field strength beyond the horizon and surface refractive index, and the geographical and climatological variability of these. MISME expressed some disagreement. He recalled that while index gradient was considered the only important parameter during the war, PERLAT had even earlier noticed the relation between surface refractivity and field strength and presented it to U.R.S.I. about a decade ago. He believed a new concept was now needed, such as « useful gradient ». He hoped that the introduction of this notion might greatly improve the correlation between radio fields and meteorological measurements and close the problem. BEAN and MISME discussed the calculation of surface refractivity and gradient from observations. NORTON interpreted the correlation between field and surface index in terms of the mixing-in-gradient hypothesis. VOGE observed that PERLAT's good correlation between field and surface index observed in Northern France was not found in the Dakar region, where the better correlation was observed with the gradient, and DU CASTEL amplified this point. BEAN disagreed with the mixing-in-gradient hypothesis as an acceptable explanation of field-surface-index correlation. WONG pointed out the similarity of index gradient everywhere above 15 000 feet, and the impossibility of understanding the correlation of field with surface index on the turbulence hypothesis. CRAIN illustrated the non-applicability of the mixing-in-gradient hypothesis with an index profile measured over Haswell, Colorado to 24 000 feet, showing the presence of a layer which had the same gradient above and below it, but vastly different index fluctuations, with great stability above the layer; he concluded that it was impossible to apply the mixing-in-gradient idea to explain measured

fluctuations normally found in the atmosphere. He based his remarks on data, not on empirical formulas arranged to fit data. NORTON replied that he believed the introduction of a vertical turbulence scale length smaller than the horizontal scale, and extremely small values of index fluctuation could explain the data. CRAIN asserted that the meteorological parameters required by turbulent scattering theories are large enough to measure in the troposphere and stratosphere if they do exist. He preferred measurements made on the atmosphere as it exists, rather than hypothetical analysis.

NAITO presented a paper by HIRAO, Document 22, « A New Type Refractive Index Variometer ». The instrument is a light weight thermistor device for measuring dry-and-wet bulb temperatures with a time constant of 0.7 sec. CRAIN described briefly radio refractometer investigations since 1951 made by more than fifteen groups in North America with the microwave refractometer developed by him. Between five and ten thousands flights have been made and are on file at the University of Texas for interested workers. His data showed typical smooth profiles, statistics of probability of occurrence of index jumps in summer and winter, temperature profiles, indicative of stability rather than turbulence caused by mixing-in-gradient, large index jumps in clear air with no visible clouds and at cloud boundaries, and a comparison of the decrease with height of the so-called « scattering parameters » required by two of Norton's interpretations of turbulent scattering theories, with the measured fluctuations on sensitive scale recordings. Measurements of scattering parameter at 4000 feet are required by the turbulence theories to be present at 100 000 feet, as well as temperature fluctuations of 10 degrees over a few hundred feet. CRAIN believed that index fluctuations decrease too rapidly with height to explain long distance fields. GORDON's view that fluctuations are larger in the stratosphere seems, on CRAIN's calculations, to require temperature fluctuations as large as 5° C there. Such fluctuations could be measured, if they existed, which CRAIN doubted. NORTON replied that he believed the observed fluctuations were sufficient for his Bessel function correlation model, that the vertical scale was more important than the horizontal scale and that the earlier calculations quoted by CRAIN were based on the wrong model and were somewhat irrelevant now.

CRAIN dissented concerning the importance of distinction between vertical and horizontal scales. RICE outlined a modified Villars-Weisskopf mixing-in-gradient calculation which he believed adequate to fit ship-to-shore 410 Mc/s radio data for distances up to 600 miles. CRAIN reiterated that evidence was against the mixing-in-gradient hypothesis in the troposphere or stratosphere. Further comments came from ABRAHAM and GORDON. SMIHT-ROSE closed the session by remarking that the session had illustrated that Commission II is young and lively, and only beginning to define its problems, while it is progressing by the usual interaction of theories and experiment.

Technical Session 5 : Monday, September 2, 1957, 14.00

Subject : *C.C.I.R. Matters and Resolutions.*

Attendance : 42.

Chairman SMITH-ROSE described briefly the origin of, and plans for, the Joint Commission on Radio-Meteorology, a combined effort of U.R.S.I., I.U.G.G. and I.U.P.A.P., whose fourth meeting had been held in New-York during August. GORDON supplied more details of this meeting, and read the resolutions adopted at it. These were confirmed unanimously by Commission II, and appear as n° 6 of the Resolutions (see attached), for forwarding to the U.R.S.I. Executive Committee.

SMITH-ROSE next outlined the work of C.C.I.R. and its relation with I.T.U. and C.C.I.F. with special reference to C.C.I.R. Study Group 5, which has similar interests to U.R.S.I. Commission II. Typical of the activities of C.C.I.R., Study Programme n° 55 was discussed (Tropospheric Propagation Curves for Distances Well Beyond the Horizon). The working subcommittee of SAXTON, GROSSKOPF, HERBSTREIT, and VOGE held meetings in Paris (1956) and Boulder (1957) to draw up improved curves of interference fields exceeded 1 % of 10 % of the time, and also curves of median fields from 40 to 500 Mc/s, systematic height gain estimates, climatic variability, differences between overland and overseas propagation, etc. WATERMAN raised the question of ionospheric interference for the lower part of the VHF frequency band. ALLEN observed that the Federal Communications Commission

did not grant protections against ionospheric interference as a policy matter. NORTON felt that television interference in the 40 Mc/s band could be acute, but SMITH-ROSE observed that in the UK and neighboring countries, the interference was tolerable on channels 1-5 with low power co-channel stations, especially with the use of cross-polarization and directive aerials. WATERMAN recalled the Commission III paper of ABEL's describing the gradual transition from ionospheric to tropospheric scatter propagation at 600 miles or more. ALLEN observed that « scatter mode » propagation was not strong enough to bother a broadcast service, but that F-layer and sporadic E propagation could interfere seriously. SMITH-ROSE outlined the answer which had been formulated to the Warsaw Question 101 « Advantages to be Obtained from Consideration of Polarization in the Planning of Broadcasting Services in the VHF (metric) and UHF (decimetric) bands (television and sound). » The answer : 18 db interference protection on the average, considerably more in open country. C.C.I.R. Questions 136, 137, 138 and Study Programmes 57, 79, 90, 91 (as listed in *U.R.S.I. Information Bulletin* 101, Jan-Feb 1957) were briefly discussed by BEAN, NORTON, BECKMANN, LUKES, RICE, ALLEN and CARROLL. It was agreed that at least two-thirds of the U.R.S.I. sessions actively considered these matters, and that useful information on these topics would be reported directly to C.C.I.R. before its next Plenary Assembly (in U. S. A., 1959). (See Resolution 5, of Commission II, below).

With some changes and additions, the resolutions attached to the U. S. A. National Committee Report of Commission II were adopted as the resolutions of U.R.S.I. Commission II (see attached) It was agreed that Doc. 155 « Radio Wave Propagation Within the Horizon », with the addition of its references, should be edited by Dr. J. B. SMYTH, Chairman of the Working group which produced it, and forwarded to the secretariat for publication in the Commission II portion of the Proceedings of the XII General Assembly.

The next chairman of Commission II would be nominated by the Executive Committee. In accord with the rotation policy of the Executive Committee, Dr. SMITH-ROSE nominated Dr. J. B. SMYTH to be Vice-Chairman, succeeding Dr. C. G. AURELL ; Dr. J. A. SAXTON to be English-speaking secretary, succeeding

Dr. T. J. CARROLL ; and M. F. DU CASTEL to be the French-speaking secretary succeeding M. J. VOGE through the next General Assembly.

Technical Session 6 : Tuesday, September 3, 1957, 09.30

Subject : *Scattering in the Troposphere* (theory).

Attendance : Average 75.

KRASILNIKOV opened the discussion with remarks concerning Doc. 86, « Theory of Wave Propagation in the Turbulent Atmosphere (Review of Works Carried out in the U. S. .S R.) » and Doc. 87 « On the Scattering Theory of Electromagnetic Waves in the Medium with Random Irregularities of the Refractive Index ». Sound, light, and radio waves must propagate through turbulence arising from convection, but it is also necessary to consider refractive effects of layers near the surface and elevated. Most Russian theoretical work in this field has been concerned with KOLMOGOROFF's theory of locally isotropic turbulence, in which many additional approximations must be made besides isotropy. Older works used geometrical optics to discuss propagation effects, but newer works also use the wave equation to discuss the amplitude and phase fluctuations introducted on a wave propagated through a turbulent layer of thickness L. TATARSKY and others prefer to use the structure function or spectrum of the turbulence rather than the correlation function. Most Russian papers on propagation through turbulence refer to sound, OBUKHOV's important pre-war paper being similar to PEKERIS' Physical Review paper. CHERNOV, MERKULOV and KRASILNIKOV have papers on the subject, including ideas on the averaging properties of receiving devices of diameter larger than the scale of the inhomogeneities. KRASILNIKOV expressed the view, that while the controversy of layer versus turbulence theories of propagation was a very complicated question, he felt the time to be ripe for a good book on the subject, written by specialists, not only as a review of the various viewpoints, but as an attempt to combine the turbulence and layer viewpoints. TATARSKY's already published and forthcoming papers in the Acoustical Journal consider questions such as spherical waves propagating through a turbulent medium. Mentioning the importance of the reversal of the sound propagation problem in

order to get information on the microstructure of turbulent flow, and the need for many measurements world-wide in scope, he expressed the belief that it would be better to know a lot about a little, than a little about a lot.

Responding to a question, KRASILNIKOV observed that the 2/3 power law dependence of the velocity and temperature fluctuations on the separation of the measurement points was well verified for experiments near the surface of the ground, and in balloon flights at times when the fluctuations existed. He believed correlation observations by two spaced refractometers to get the structure (spectrum) function would be very useful for the propagation problem. WONG described some non-ideal attempts with a refractometer in level flight at 14,000 feet to determine the power law, in which fluctuations down to 2 feet in size could be resolved. SILVERMAN remarked on the spread of the exponent in TATARSKY's measurements, and on the importance of trying to decide at least whether the exponent is less than, equal to, or greater than I, as an aid in experimentally distinguishing between various types of spectrum function. CRAIN observed that early Texas measurements on temperature fluctuations with thermistors gave different spectra parallel and perpendicular to the wind. KRASILNIKOV replied that TATARSKY's measurements in agreement with the 2/3 power law are only for experimental conditions fitting the idealized theory. Because the whole matter is statistical, much more work is needed to verify the theory in general. AMENT expressed the opinion that lack of isotropy under conditions of wind shear near stratified layers would be very important to turbulent scatter propagation. CARROLL inquired about the possibility of extrapolating turbulent measurements near the surface to points high in the troposphere and stratosphere. KRASILNIKOV saw no possibility of such extrapolation without measurements, except as a hypothesis to see if the KOLMOGOROFF law is applicable.

WHEELON summarized Doc. 302 and listed nine types of data which theories must be able to explain :

1. Frequency dependence of fields beyond horizon;
2. Distance dependence (exponential or an inverse 5th to 8th power law);
3. Correlation of meteorology with field strength;

4. Statistical properties of signal, such as Rayleigh fading ;
5. Fading rate, and its proportionality to frequency ;
6. Space correlation experiments ;
7. Effective antenna gain measurements and height gain degradation ;
8. Narrow beam swinging experiments.
9. Bandwidth possibilities or frequency correlation, as a function of distance.

WHEELON's further remarks referred mainly to theories based on the hypothesis of scattering from turbulence, which has been assumed in many theoretical papers, with a few added remarks about recent elevated layer hypothesis, leaving the Carroll-Ring mode theory of a gravitationally stratified layer to be expounded later by CARROLL. Turbulence theories usually assume either the autocorrelation function such as the exponential, $\rho K_1(\rho)$, or Gaussian, or else the spectrum power law. WHEELON regarded the $K^{-11/3}$ spectrum derived from OBUKHOV and the mixing-in-gradient considerations, and the K^{-5} law derived from mixing-in-gradient considerations and the Navier-Stokes equations as the only legitimate theoretical models of homogeneous turbulence, with frequency dependence experiments favouring the latter alternative. He believed that some agreement with categories (4)-(9) above could be claimed by turbulence theories but noted some disagreements between anisotropic turbulence calculations of effective antenna gain, and bandwidth estimates. He touched briefly on the FRIIS, CRAWFORD, and HOGG calculations based on the hypothesis of elevated reflecting « platelets », and their interpretation of some beam swinging, wavelength dependence, and gain degradation experiments. SILVERMAN did not agree that the two spectrum laws quoted by WHEELON had equally good theoretical foundation. He believed that K^{-5} law is not well supported theoretically, as also does BOLGIANO, and that the mixing-in-gradient plays no role in the smaller eddies. ROCHE described calculations for narrow beam common volume integrations assuming rectangular beams, which did not agree with experiment by about 20 db at the longer ranges. CARROLL pointed out that MEGAW's posthumous paper pointed to an error in the K^{-5} derivation of VILLARS and WEISSKOPF, so that

the claimed experimental frequency dependence favouring this theory may be an illusion. WHEELON argued that MEGAW died before seeing a good derivation of the K^{-5} law, while SILVERMAN observed that probably VILLARS and WEISSKOPF no longer believed in it.

EKLUND's question about frequency dependence of scattered fields was answered by NORTON, who referred to his 1955 paper as having shown the power law exponent to be 1.04 ± 0.2. RICE said his common volume integrations did not give too low an answer at long ranges as did ROCHE's, and added that the case of unequal antenna beams had also been treated. He suggested that the measurements were more uncertain than the theory. WATERMAN pointed out differences between volume scattering and layer type reflections on beam swinging and gain degradation experiments. BULLINGTON observed that longer paths at 200 Mc/s do not always follow the Rayleigh distribution, with only two or three randomly fading components being needed to explain the fading. AMENT said that pulse transmissions over a path in the Bahamas sometimes indicate a small number of components. NORTON believed that experiments do agree with turbulence theory calculations. SMYTH objected that few people had ever really checked the presence of a Rayleigh distribution by setting up a statistical chi-squared test, with confidence limits better than coin spinning.

GORDON next amplified Doc. 245, on the role of the stratosphere, as distinct from the troposphere in radio communications. (See Proc. I.R.E., Sept. 1957). Using the mixing-in-gradient hypothesis, the excess of the index gradient over adiabatic is taken to be the determining factor for the intensity of dielectric constant irregu larities. This allows turbulence scattered fields to be calculated for the stratosphere in excess of those based on CRAIN's measured estimates of tropospheric turbulence extrapolated to the strato-sphere. GORDON believed experiments on the correlation of fields with the height of the tropopause are needed, and that stratospheric temperature fluctuations of the order of a degree C are required by his hypothesis. He mentioned that the strato-spheric calculations indicate a maximum realizable antenna gain of about 38 db independent of distance, and an optimum elliptical shape of antenna aperture. RICE compared American experi-

mental data from several sources with calculations based on the $\rho K_1(\rho)$ model. ROCHE pointed out the small seasonal variability (5 db) of 400 Mc/s fields over a 600 mile path, and AMENT recalled that the fields exceeded 99 % of the time were more stable than the medians.

ECKART discussed the inverse scattering problem, also worked on by GELFAND and LEVINTHAN in U. S. S. R., and KAY in U. S. A. He drew attention to several points discussed in his papers (see G. ECKART, Bavarian Academy of Sciences, vol. 77). « The Analysis of Perturbations of the Dielectric Constant of Dielectrically Turbulent Zones by Means of Scattered Field Observations » emphasizing the point that phase as well as pulse envelope amplitude observations are necessary to draw conclusions about dielectric turbulence giving rise to scattering, using the method of inverting Fourier transforms. SMYTH presented the results of reflection coefficient calculations for plane waves incident on layers stratified according to (*a*) the analytic Epstein layer, and (*b*) a sinusoidal layer with second derivative discontinuities at the boundaries. The exact calculations (based on hypergeometric and Matthieu differential equations), for 89° angle of incidence, $60 \times (10)^{-6}$ index change for the Epstein layer and 93 % of this for the sinusoidal layer, came out $1.2 \times (10)^{-7}$ and $1.6 \times (10)^{-5}$ respectively. The exact calculations proved, SMYTH observed, the need for caution in theoretical modelling, because experimentally one could never distinguish between the two types of transition. CARROLL stated he disagreed on almost every point with WHEELON's interpretation of the meaning of the experimental data. Despite its historical usefulness, he argued that the meteorological and mathematical assumptions underlying the turbulence explanation were probably wrong, and that he bilieved the true explanation of reliable fields beyond the horizon came from applying Furry's theory of transitional ducts (bilinear model) to the gravitationally stratified layer, the « twilight » region fields being conceived to be waves guided around the earth as coherently scattered waves in the air dielectric. He predicted that the popularity of the Turbulence explanation at the Zurich, Sydney, and The Hague Assemblies of U.R.S.I. would have withered by the next assembly.

Technical Session 7 : Wednesday, September 4, 1957, 09.30

Subject : *Scattering in the Troposphere.*

Attendance : Approximately 75.

Chairman SMITH-ROSE asked for comments on the resolutions adopted at Technical Session 5, which had been typed and posted. He then read a new resolution submitted by Professor KLEIN of New-York University concerning the mathematics of wave propagation in inhomogeneous media. Discussion followed by HERBSTREIT, who preferred a more general wording, and CARROLL who endorsed the resolution as read. The resolution was then adopted, and appears as the third of the Commission II resolutions in the list attached. WHEELON's suggestion during Technical Session 6 for a summary of agreed experimental facts on this subject, unadulterated by theoretical interpretation, was discussed by GORDON and AURELL. SMITH-ROSE concluded that the task was too large for the present meeting, and expressed the hope that interested workers might communicate their ideas in writing to the Commission II secretaries, in the hope of developing and circulating a synopsis of experimental facts, condensed but including the significant properties.

With Vice-Chairman AURELL presiding, CARROLL presented the idea underlying the coherent scattering from of tropospheric reflection theory as an alternative to turbulent scattering theories. While turbulence and coherent scattering are not mutually exclusive, he argued that it was now possible to assert that scattering by turbulence was relatively unimportant in understanding the cause of useful observed fields well beyond the horizon, notwithstanding the historical usefulness of the hypothesis in directing attention to neglected experimental facts.

CARROLL briefly traced the historical development of this alternative approach, and led up to the initial application of Furry's theory of transitional modes for bilinear model atmospheric index profiles. (See Carroll-Ring papers in October issue of 1955 Proc. I.R.E. and May, 1957 issue of l'Onde Electrique). Since 1954, calculations of mode sums has been extended on the Whirlwind Digital Computer, by Dr. RING and Professor DWIGHT of M.I.T., for three frequencies (on the bilinear model) : 50 Mc/s, terminal heights 1000 feet and 1000 feet, 500 feet and 30 feet ; 410 Mc/s

for terminal heights 40 feet, 10 feet; 3000 Mc/s for terminal heights 117 feet, 71 feet. Mode sums for the inverse-square profile with zero gradient at the air-to-free-space transition are now complete for 500 feet and 30 feet terminal heights at 50 Mc/s. The mode sums agree both as regards amplitude and phase with classical ray theory or mode theory corrected for refraction within and just beyond the horizon, and also possess a twilight region well beyond the horizon. CARROLL said that he believed the same mode theory calculations gave a new way of understanding the duration of optical twilight, as well as the phenomenon of the « Gegenschein » or counter glow, whose apparent parallax has been measured in U. S. S. R. in recent years. The elaborate mode summing calculation for the various linearly and curvilinearly tapered index profiles, CARROLL regarded as only necessary to be carried out for a few examples, in order to show that fields in the optical, diffraction and twilight regions could be calculated from a single mode representation. For practical purposes simpler approximate methods may be used for the separate regions. Twilight region fields could be conceived to be simply the result of the presence of the earth's air layer, stratified by gravity and the gas laws, without assumption of any other properties in the troposphere or stratosphere.

Chairman AURELL observed that while the coherent and turbulent scattering mechanisms were not mutually exclusive, the question of which was dominant still needs an answer. FINE asked about the comparison between the inverse square and bilinear models in the twilight region. CARROLL replied that for the 50 Mc/s calculation the field strength for inverse square model averaged about 60 db below the bilinear model value. He asserted that the best model for understanding the data was one intermediate between the two, a terminated exponential profile, in which the termination to free space may be imagined at the level where the refractive index becomes unity at the boundary between the stratosphere and the lower ionosphere. WAIT raised the question of BREMMER's use of the Eckersley-Millington profile, to extend the airless earth solutions, on which there is agreement, to some form of inhomogeneous atmosphere. CARROLL replied that the Eckersley-Millington profile, when fitted to have the proper surface index and gradient, is badly in error at great heights.

BREMMER pointed out that his derivations based on the Eckersley $n^2 = A + B/r^2$ profile were intended to show that the 4/3 earth notion appears automatically for this profile by use of a similarity argument, and that this derivation therefore goes beyond the geometrical optical notions by which the effective radius idea was originally introduced. RICE inquired about the second drop-off in a mode sum calculation beyond distances at which no air dielectric in intervisible by rays from the terminals. CARROLL replied that the terminated exponential model would have the second drop-off beyond any existing data. CARROLL emphasized that his profiles were all two-piece analytic functions, and that the wave function had to be a linear combination of the two solutions of the wave equation for heights in the inhomogeneous air layer, or else what Furry once called a « bogus formula » would result. While the « joint » in the profile representing the air-to-vacuum transition can be made as small as desired by taking it high enough, the limiting case of infinite transition height was unsolved yet because of the restriction in earth curvature diffraction problems to source heights small compared to the earth radius. The twilight region mode of maximum contribution was interpreted as radiation leaving the surface tangentially, and making the air-to-free-space transition at a definite height with a small associated reflection. The specularly reflected ray from the transition height would in practice not be excited appreciably as a consequence of the radiation pattern of the antenna.

KATZIN observed that normal mode theory was based on strict horizontal stratification, necessary to allow separation of the variables. He inquired about the mode theory approach to variability of signals in time and space : fading, diversity distances, bandwidth, etc. CARROLL replied that random fading of a small number of modes or elevated layers could account for a Rayleigh distribution of the short term fading of twilight region fields. While turbulence is a possible contributor to random phasing of the modes at large distances, he preferred the molecular motions of kinetic theory as the most probable cause of the omnipresent fading such as had been observed in experiments in the Arizona desert. It was suggested that a frequency spread up to a few cycles/sec in the received signal would result from Doppler frequency shifts due to moving molecular layers. KATZIN interjected

that he could agree with arguments based on moving scatterers, but deemed such considerations outside normal mode theory. BREMMER advanced the idea that perhaps mode theory could be modified to explain fading by considering the expansion cœfficients to be slowly varying functions of the time, perhaps in consequence of making the index of refraction a function of time as well as of height, as in turbulence. CARROLL welcomed BREMMER's idea if it could be carried out, but stated his own approach to fading was more simply based on the moving mirror and Doppler concept added to mode theory calculations for an inhomogeneous gravitational distribution of stationary molecules. He further expressed the view that turbulence theories of micrometeorological variability of refractive index only succeeded in explaining data by the assumption of sharp-sided blobs introduced through the exponential autocorrelation function in the BOOKER-GORDON paper, which he believed to be inadmissable in a gaseous medium like air. SILVERMAN expressed doubts about the feasibility of explaining fading following a Rayleigh distribution by introducing turbulence into mode theory. GORDON asserted that BOOKER and GORDON still believed in their original form of turbulent scattering theory with an exponential autocorrelation function.

NORTON presented some results of calculations of turbulent scattering based on the Bessel-type autocorrelation function assuming anisotropic turbulence. The calculations differ from those of STARAS (Ref. 1 and 31 of Doc. 302), and show less effect of anisotropy on spaced antenna correlations and antenna gain degradation. SILVERMAN inquired about the validity of assuming anisotropy even for the smaller eddies. NORTON replied that the Bessel-type correlation function used is probably inaccurate for the smaller blobs. Answering GORDON's query, NORTON said that the scales of turbulence dropped out in integration over the scattering volume. RICE outlined some refinements in scattering volume calculations of antenna gain degradation. He stressed the differences in method between this type of threedimensional integration over the scattering volume, compared with STARAS's procedures, as well as the differing assumptions about the height decrease of the scattering parameters. The results disagreed with BOOKER-DE BETTENCOURT results, his own October 1955 publication, and with the assymmetrical antenna cases of STARAS.

Replying to GORDON, RICE said his calculations gave in general less antenna gain degradation than those of BOOKER and DE BETTENCOURT.

BEAN next presented studies of surfaces index of refraction in U. S. A. as deduced from 8 years of weather station observations. Separate maps were shown for the « dry » and « wet » contributions to the index of refraction. MISME maintained that he could see no point in drawing separate maps for the dry and the wet terms. The validity of surface index alone as a criterion of total refractive bending for tangential rays was disputed somewhat. AURELL closed this final session of Commission II with the observation that complete agreement had not been expected on many points. Clearly there was need for further work which would be similarly talked over three years hence at the next assembly.

Report on the Meetings of Commission II

at the Plenary Closing Session

5 September 1957

by R. L. SMITH-ROSE, *Chairman*

Commission II has held 8 sessions, all of which have been attended by some 70 delegates and observers. Although the various authors of documents distributed to the Assembly presented accounts of their work, the meetings were by no means limited to these ; and a majority of those present participated in some very interesting and lively discussions.

The subject of the Commission was essentially divided into four parts. The first dealt with the effect of the ground on the propagation of very short radio waves, and particularly with the fields that can be measured beyond mountain ridges and similar obstacles. The manner in which the waves are bent or refracted in the lower atmosphere was next discussed. Some valuable contributions were made describing radio field strength measurements made both within and beyond the horizon distance from the transmitter. These were associated in many cases with meteorological observations. But in addition a large mass of information is now available on the vertical gradient of refractive index of the atmosphere obtained from radio sounding balloon technique.

At the various meetings there has been much speculation and diversity of opinion as to how the radio waves are propagated to relatively great distances — several hundred kilometers, in the lower atmosphere. For want of a more precise description, the process is termed « scattering », but several theories abound and were discussed, in an attempt to understand the precise thermodynamic conditions in the atmosphere that make such propagation

possible. In some phases of our discussions, it seemed that we must take account of meteorological conditions at heights up to about 30 km. This may take our studies beyond the limits of the troposphere, but it is not proposed to suggest any alteration in its title of the Commission at the present time.

A brief report with an extensive bibliography, has been prepared reviewing the present state of knowledge of the propagation of very short radio waves to distances within the horizon. It has been recommended that this report should be published in Proceedings of the Commission at this XII General Assembly.

In conclusion, I may say that while we are rapidly increasing our knowledge of the subject of our Commission, we still do not have a very clear understanding of the manner in which very short radio waves travel through the lower atmosphere. The further investigations that are necessary are illustrated by the Resolutions adopted by Commission II, and which I will now summarize.

I should like to take this opportunity of thanking Dr. C. G. AURELL, vice-Chairman, for taking the chair at two sessions in my absence ; and particularly to express my appreciation of the excellent secretarial services given by Dr. T. J. CARROLL and Mr. J. P. VOGE during the whole General Assembly. For the future, the Commission approved the appointment of Dr. J. B. SMYTH as vice-Chairman and Dr. J. A. SAXTON as Secretary for the English language.

Resolutions

1. It is recommended by Commission II at the XII General Assembly that :

(*a*) The extent of the dependence of scattered signals on latitude, climate and terrain should be further studied by means of observations in differing geographical areas.

(*b*) In particular, measurements of field strengths from high-power transmitters should be made at great distances and for various frequencies, polarization, antenna heights and gains, and various types of terrain. Use of aircraft in such measurements is recommended.

(*c*) Propagation studies should be extended to include investigation of pulse distortion, phase stability, fading rates, and diversity properties of the signal.

(*d*) Simultaneous meteorological measurement designed to improve understanding of the propagation mechanism are desirable.

(*e*) Quantative knowledge of the means of relating the above findings to practical radio results should be extended, especially in the direction of providing satisfactory approximations.

2. In view of the importance of conditions in the lower atmosphere to the propagation of the shorter radio waves, it is recommended that U.R.S.I. take steps to insure that national meteorological authorities are aware of the need of radio scientists for meteorological observations ; and that such observations should be organized so as to provide as much information as possible for application in the radio field. It is recommended that national meteorological authorities should be encouraged to :

(*a*) Perform more detailed meteorological measurements, including those with airborne equipment, with emphasis on the study of the fine structure of the atmosphere. Special attention should be given to the detailed variation of the refractive index in the

region where this index undergoes significant changes. The use of the refractometer for such measurements is strongly recommended.

(*b*) Complete meteorological data of the nature described under (*a*) for the purpose of using these data as a help in prediction, on a statistical basis, of the propagation characteristics to be expected in various geographical regions.

3. It is recommended that, whenever possible, meteorological measurements of a sufficiently detailed character to throw light on the mechanism of propagation be carried out in conjunction with programmes of propagation measurements. It is suggested that several varieties of atmospheric phenomena and methods of study are directly or indirectly germane to tropospheric radio propagation ; hence, multi-purpose meteorological and radio signal measuring programmes are recommended as mutually beneficial and economic.

4. It is recommended that the mathematical problem of the propagation of electromagnetic waves in an inhomogeneous medium with a refractive index which is a function of height above a spherical earth, be further investigated with a view to determining as accurately as possible the field transmitted around the earth. The mathematical investigation shall in particular seek better knowledge of the eigenvalues belonging to the various modes, and a better determination of the height gain functions. Alternatively, any other method, which permits the determination of the fields either exactly, or with an estimate of the error, should be pursued.

5. Commission II, in noting the C.C.I.R. Questions 101, 136, 137 and 138, and the Study Programmes 55, 57, 79, 90 and 91 reports that more than two-thirds of its sessions at the XIIth General Assembly were devoted to active discussion of work relating directly to these subjects from many different organizations. It is clear that useful results are being achieved, and will be communicated to C.C.I.R. by various administrations before the next plenary meeting.

6. Commission II concurs unanimously with the following statement of purpose of the Joint Commission on Radiometeorology as formulated at its meeting of August 16, 1957.

That the 1957 meetings of the Joint Commission had provided a successful forum in which specialists in radio science, meteorology, and physics had a unique opportunity to describe their experiences and exchange knowledge about phenomena in the lower atmosphere in which they had a mutual scientific interest, and the following resolutions were adopted unanimously :

(*a*) That the Joint Commission should continue as a forum with a reasonable balance of radioscientists, meteorologists, and as may be necessary other physicists, whith whom the radiometeorologists can exchange knowledge and experience.

(*b*) That the programme for the immediate future should be :

(1) study of vertical and horizontal air movements and refractive index structure including formation of clouds and precipitation and application of the results to radio wave propagation and meteorology.

(2) study of electrical fields in the atmosphere with special reference to thunderstorms.

(*c*) That the constituent Unions be invited to review their representation on the Commission and make fresh appointments where necessary.

(*d*) That the next meeting of the Commission be held in 1960.

(*e*) That the papers for presentation at the next meeting be submitted to the President of the Commission for approval three months before the meeting.

(*f*) That the Commission wishes to convey its warmest gratitude to the President of New-York University and his staff, particularly Prof. Morris Kline for the facilities, assistance, and hospitality provided in connection with the Commission's meeting.

7. During the I.G.Y. the needs of radio scientists studying tropospheric wave propagation should continue to be met by the following programme :

(*a*) Radiosonde data up to heights as high as possible be published in as much detail as the precision of the instrument permits. During World Meteorological Intervals the number of soundings should be at least four per day.

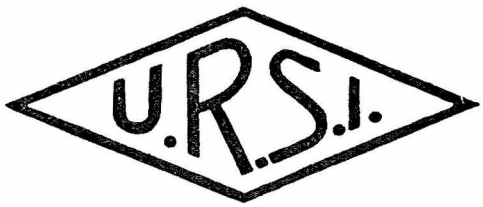
(*b*) It is suggested that where possible supplementary observations

should be made of meteorological data at lower levels using captive balloons or masts.

(*c*) Where possible airborne microwave refractometer soundings should be made in various air masses to ascertain the characteristics of the air masses with respect to the vertical distribution of refractive index and the scale and intensity of its fluctuations.

(*d*) The attention of the meteorologists should be drawn to the refractometer as a rapid instrument for the determination of water vapor content when used in conjunction with a temperature measuring element. The refractometer soundings described in (*c*) above have a direct usefulness to the meteorologists in this regard.

INTERNATIONAL SCIENTIFIC RADIO UNION



Proceedings of the XIIth General Assembly

held in Boulder, Colorado, U. S. A.
from August 22nd to September 5th, 1957

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COMMISSION III

On Ionospheric Radio

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Yugoslavia : Dr. Ing. Dejan BAJIÉ, Instiut « Nikola Tesla », Belgrade, Boîte Postale 906.

Sub-Commissions

III*c*. — *On Study of Propagation Time of Radio Signals*

Chairman : Prof. M. BOELLA.

Members : P. V. AKERLIND,
Dr. H. Th. FLEISCHER,
Dr. W. D. GEORGE,
Prof I. KOGA,
Sir K. S. KRISHNAN,
Father P. LEJAY,
Dr. R. L. SMITH-ROSE,
Dr. J. J. VORMER,
Dr. V. D. R. WOOLEY.

III*e*. — *On Ionospheric Indices of Solar Activity*

Chairman : Dr. W. J. G. BEYNON,

Members : Prof. C. W. ALLEN,
Dr. D. H. MENZEL,
Mr. C. M. MINNIS,
Mr. A. H. SHAPLEY.

Drafting Committee of the Special Report on :
« Radar Observations of the Aurora »

Chairman : Dr. J. H. CHAPMAN.

Members : Dr. H. G. BOOKER,
Dr. C. D. ELLYETT,
Dr. L. HARANG,
Prof. A. C. B. LOVELL,
Dr. L. OWREN.

List of reports and papers submitted to the Commission

The asterisk indicates reports published in this part.

E = Original text in English.

F = Original text in French.

N°	Titles and Authors
1	C.C.I.R. Findings of interest to the U.R.S.I. (E).
23	Dynamical structure of the ionospheric F2 layer as deduced from its daily variations, T. SHIMAZAKI, Radio Research Laboratories, Kokubunji, Tokio (E).
24	On the occurrence of the F1,5 at Tokyo, I. KASUYA, *Ibid.* (E).
25	Some results of a sweep-frequency propagation experiment over a north-south path at a distance of about 1000 km, Y. AONO, I. KURIKI, *Ibid.* (E).
26	Measure of magnitude of sudden ionospheric disturbance, Y. NAKOTA, *Ibid.* (E).
27	On radio propagation disturbances, K. SINNO, Hiraiso Radio Wave Observatory, Radio Research Laboratory (E)
28	Ionospheric F2 disturbances associated with geomagnetic storms, T. SATO, Geophysical Institute, Kyoto University, Kyoto, Japan (E).
30	On sequential Es, S. MATSUSHITA, *Ibid.* (E).
31	Remarkable lateral deviation in the ionospheric propagation, K. MIYA, M. ISHIKAWA, S. KANAYA, Kokusai Denskin Denwa Co., Ltd. Japan (E).
32	A new theory of formation of the F2 layer, T. YONEZAWA, Radio Research Laboratory, Kokubunji, Tokyo (E).
33	Magneto-hydrodynamic waves in the ionosphere, S.AKASOFU, Geophysical Institute, Tohoku University, Sendai, Japan (E).
34	Calculation of the propagation path of whistling atmospherics, K. MAEDA, I. KIMURA, Department of Electronic Engineering, Kyoto University (E).

N°	Titles and Authors
35	The difficulties in explaining the formation of the ionosphere, Y. INOUE, Technical Research Institute, National Defence Agency, Tokyo (E).
65	Method of Ionospheric prediction, E. CHVOJKOVA, Astronomical Institute, Ondrejova (E) (*Publ. Astron. Czechosl.*, 26, 1955 ; *C.C.I.R.*, 1956, Doc. 219).
66	A new possibility of long-distance propagation of metric waves, Same author (E) (*Bull. Astr. Czechosl.*, 5, 1954 ; 104-108, 110-111).
67	Refraction of radiowaves in an ionised medium, Same author (E) (*Ibid.*, 5, 1954, 99-104, 104-108).
69	Ionospheric layer during photo-ionisation, Theory of bifurcation and rocket research, Same author (E) (*Ibid.*, 4, 1953, 20, 101-109 ; 1956, 33-38, 1957).
70	On the relation between the night E-layer above Lindau-Harz and the geomagnetic activity, A. HAJKOVA, J. MRAZEK (E).
71	Measuring of the number of fadings, P. TRISKA (E).
72	On the presence of a sporadic E-layer above Lindau-Harz during the period between 1948 and 1955, J. MRAZEK (E).
77	The nocturnal ionisation of the E-region and the geomagnetic activity, A. HAUBERT (F).
78	On large vertical motions in the F-region, observed in Casablanca, A. HAUBERT (F).
79	The temperature gradients in the E and F1 regions, from ionospheric soundings in Casablanca, A. HAUBERT (F).
88	On the theory of propagation of radio waves in the ionosphere, V. L. GINZBURG, P. N. Lebedev Institute of Physics, U S.S.R. Academy of Sciences (E).
89	Scattering of radio waves in the ionosphere and long-range propagation of ultra-short waves, J. L. ALPERT (E).
90	Analysis of the waveforms of atmospherics and the velocity of audio frequency electromagnetic waves, J. L. ALPERT, S. V. BORODINA (E).
91	Investigation of the ionosphere layer of height irregular structures during simultaneous receptions at different frequencies, V. D. GUSSEV, S. F. MIRKOTAN, M. S. U., Faculty of Physics, U.S.S.R. (E).
92	Investigation of ionospheric irregularities by means of measuring phase path variations of radio-pulse reflected from the ionosphere, V. D. GUSSEV, L. A. DRATCHEV, *Ibid.* (E).

N°	Titles and Authors
104	Preliminary results of an investigation of propagation conditions at very low frequencies, R. LINDQUIST, Research Board of National Defence, Stockholm, Sweden (E).
116	Lunar tidal variations of midday critical frequencies and lowest night-time critical frequencies of the F2 layer at Slough and Lindau, G. LANGE-HESSE, E. SCHOTT, Max-Plank Institut für Physik der Ionosphäre, West-Germany (E).
124*	Report of the British National Committee to Commission III, W. J. G. BEYNON (E).
145*	Report of the Chairman of Sub-Commission III*b* (F).
158*	Report of the New Zealand National Committee to Commission III (E).
161*	Report of the Italian National Committee to Commission III (E).
167*	Report of the Netherlands National Committee to Commission III (E).
169*	Report of the Morocco National Committee to Commission III (F).
172*	Report of the Czechoslovakian National Committee to Commission III (E).
177	On the origin of radar echoes associated with auroral activities, J. MEOS, S. OLVING, Research Laboratory of Electronics, Chalmers University of Technology, Götheborg, Sweden (E).
186*	Report of the Canadian National Committee to Commission III (E).
192*	Report of the German National Committee to Commission III, W. DIEMINGER (E).
199*	Report of the Japanese National Committee to Commission III, S. NAMBA (E).
206*	Report of the Polish National Committee to Commission III (E).
215*	Report of the Swedish National Committee to Commission III, S. GEJER (E.)
223	Report of the Australian National Committee to Commission III (E).
228*	Report of Commission III*c* of the Japanese National Committee, I. KOGA (E).
234	Electromagnetic wave reflection and space charge wave propagation in electron stream, O. E. H. RYDBECK, Research Laboratory of Electronics, Chalmers University of Technology, Götheborg, Sweden (E).

N°	Titles and Authors
251	Further experiments on the non-linear effects in the ionosphere, M. CUTOLO (E).
252	Remarks on the theories of self demodulation of radio-waves in the ionosphere, M. CUTOLO (E).
253	Correlation between E-layer and the 500 MB surface position of gyro-interaction, M. CUTOLO, A. NAPOLETANO (E).
263	Drift motions of auroral ionization, B. NICHOLS (E).
274	Magneto-ionic theory and E-region. Triple forked traces, D. LÉPÉCHINSKY, Laboratoire National de Radioélectricité, Paris (F).
275	Propagation of a plane electromagnetic wave through an ionized layer of finite thickness in the presence of collisions, P. POINCELOT, L. ROBIN (F).
279	The third magneto-ionic reflection level, J. W. WRIGHT (E).
280	Various types of low frequency reflection in the ionosphere, H. POVERLEIN (E).
281	Measurement of ionospheric winds, P. LEJAY, Laboratoire National de Radioélectricité, Paris (F).
282	Solar ionizing radiation effective in lower ionosphere, H. FRIEDMAN, T. A. CHUBB, J. E. KUPPERIAN Jr. (E).
283	Ionospheric storm analysis from « *f*-plots », A. H. SHAPLEY, National Bureau of Standards (E).
284	The morphology of ionospheric storms, M. SUGIURA, R. NORTON, *Ibid.* (E).
285	Mode identification, MUF and wave angles in long distance high frequency propagation, R. SILBERSTEIN (E).
286	VLF ionospheric propagation, J. R. WAIT (E).
287	World-wide observations of short wave fadeouts, J. V. LINCOLN (E).
288	Ionospheric electron densities and differential absorption, J. C. SEDDON, J. E. JACKSON (E).
289	Ionospheric soundings at low frequencies, J. M. WATTS (E).
290	Ionospheric effects of the great solar outburst of February 23, 1956, R. W. KNECHT (E).
291	The thermal and gravitational excitation of atmospheric currents, M. C. WHITE (E).
297*	Report of the U. S. A. Commission III (E).
303	A fading origin experiment for radio waves reflected from the ionosphere, T. N. GAUTIER, R. S. LAWRENCE, W. F. UTILANDI, B. WIEDER (E).
305	Influences of the absorption on the ionospheric reflection coefficient, P. POINCELOT (F).

N°	Titles and Authors
306	Report of the Chairman of the Permanent Committee on Ursigrams (F).
309	On the reflection coefficient of the ionospheric layers, Geneviève PILLET, Laboratoire National de Radio-électricité, Paris (F).

N° 145 - Report from the Chairman of Sub-Commission IIIb

on Radio Wave Interaction

E. Picault

(*Translation*)

Works interesting Sub-Commission III*b* were not numerous during the recent years. A bibliography was published in *U.R.S.I Information Bulletin*, n° 97, May-June, 1956.

The following works submitted to the Colloquium on Radio Waves Propagation held in Paris, September 1956, should be mentioned :

Prof. Cutolo (Naples, Italy) : Recent experiments on radio waves selfmodulation in the ionosphere.

Prof. Goldstein (Urbana, Illinois) : Interaction of radio frequency electromagnetic waves in ionized gases and their effects on ionospheric phenomena.

Prof. Bayet, Delcroix and Denisse (Toulouse and Paris) : On interaction phenomena theory.

The study published by these authors in the « *Journal de Physique et le Radium* » on the cinetic theory of slightly ionized homogeneous plasma (4 papers) should also be mentioned.

It seems premature to draw conclusions from the works carried out previously and it is desirable to continue experimental investigations.

Collaboration with C. C. I. R.

The Plenary Assembly of C.C.I.R. held in Warsaw in 1956 invited the co-operation of U.R.S.I. on the following topics relevant to the field of Commission III.

Recommendation n° 59. — Exchange of information for the preparation of short-term forecasts and the transmission of ionospheric disturbance warnings.

Report n° 62. — Investigation of circularly polarized emitted waves propagated via the ionosphere.

Resolution n° 26. — Ionospheric sounding stations after the I.G.Y.

Resolution n° 27. — Noise-linear effects in the ionosphere.

Study Programme n° 60 (VI). — Basic prediction information for ionospheric propagation.

Study Programme n° 63 (VI). — Radio propagation at frequencies below 1500 kc/s.

Study Programme n° 66 (VI). — Study of fading.

Study Programme n° 92 (VI). — Choice of basic index for ionospheric propagation.

Study Programme n° 93 (VI). — Identification of precursors indicative of short-term variations of ionospheric propagation conditions.

Study Programme n° 97 (VI). — Pulse transmission tests at oblique incidence.

Study Programme n° 98 (VI). — Back-scattering.

Study Programme n° 99 (VI). — Estimation of sky-wave field strengths on frequencies above 1500 kc/s.

The Plenary Assembly called also the attention of U.R.S.I. on :

Report n° 54. — Long distance propagations of waves of 30 to 300 Mc/s by way of ionization in the E and F regions of the ionosphere.

Report n° 57. — Choice of basic index for ionospheric propagation.

Report n° 58. — Exchange of information for the preparation of short-term forecasts and the transmission of ionospheric disturbance warnings.

All the above topics have been published in *Information Bulletin*, n° 86, pp. 31-50 (July-Aug. 1954), and n° 100, pp. 55-63, and pp. 71-78 (Nov.-Dec. 1956).

National Committee Reports

Australia

Nº 223. — Report of National Committee to Commission III

(i) Radio Research Laboratories (Camden and Sydney)

Work has been done on the theory of the anomalous geographical seasonal and diurnal behaviour of this region. A special study has been made of the perturbations of the region by lunar tidal influences. This has very satisfactorily confirmed the general picture developed earlier of the mechanisms by which the region is perturbed and has given a quantitative explanation of the lunar perturbations.

Special attention has been given to the effects of diffusion of ionisation in the F2 region, the relevant theory being developed in detail. It is found that diffusion is an important though not the dominant factor in F2 behaviour, particularly at night in moderate to high latitudes. A layer will assume by diffusion a Chapman form at a steady height in a few hours' time if air densities in the F2 region are those previously deduced by R.R.L. On the other hand if rocket measured densities are accepted this process should occur in a few minutes. Observations shows that the process requires some hours, thus suggesting that rocket-measured densities are seriously in error. This way vitally concern the I.G.Y. satellite programme, which is based on a satellite life-time of about a year. If R.R.L. estimates are correct a satellite in an orbit 300 miles above the earth will stay up for only a few weeks, at best.

Early in 1957 an airglow photometer designed by Dr. Roach was installed at Camden by Mr. Megill of the National Bureau of Standards, Boulder, Colorado. It is hoped that this instrument, in conjunction with other radio instruments at Camden, will throw light on movements in the E region of the ionosphere.

Also in process of installation is a back-scatter P.P.I. ionospheric recorder of the type designed by Dr. Peterson of Stanford University, and an all-sky camera for the usual recording of aurorae and of cloud cover.

(ii) Study of Travelling Ionospheric Disturbances has continued at Sydney and field stations at Camden and Blaxland approximately 40 km southwest and west of Sydney respectively. Two extra stations were operated over a 3 month period to increase the spacing to approximately 100 km to give more information on the horizontal dimensions of disturbances. A panoramic (ionosphere sounder) ionosonde is used at Camden to supplement fixed frequency observations at the three spaced points.

For selected periods all ionosondes in Australia have been operated more frequently than usual to facilitate tracking of large disturbances.

The general results show (*a*) that all disturbances have a much greater extent perpendicular to the direction of travel than along it, (*b*) the smaller disturbances observed on *h't* records have dimensions of the order of tens to hundreds of kilometres while the larger ones observed more particularly on *h'f* records have dimensions of the order of hundreds of kilometres (short dimension) to thousands of kilometres (long dimension).

The large disturbances particularly evident as anomalous cusps on records may travel for thousands of km with reasonably constant characteristics.

The direction and speed of travel of disturbances have followed a consistent pattern of annual and diurnal variations until 1956 when marked changes have appeared apparently as a result of the increasing sunspot cycle.

It has been shown that many anomalies on *h'f* records are the result of deviation of ray reflection paths rather than stratification, and that since these anomalies are mostly caused by travelling disturbances they may be utilised in tracking the progress of such disturbances over a network of ionosonde stations.

Similar considerations show that past interpretation of ionosonde records taken during solar eclipses may be seriously in error because of the failure to consider returned ray paths which must deviate from the vertical.

Observation of the occurrence of patches of E*s* on *h't* records

at the sites mentioned above have shown that the direction of progress is generally different from that of F region disturbances occurring about the same time. In general there is little seasonal or diurnal change in velocity of movement. They occur mainly during a limited period of the day and mainly in summer.

(iii) University of Queensland

1. — *F Layer irregularities*

By the use of (*a*) *h't* stations spaced 100 km apart, (*b*) equipment for recording direction-of-arrival of echoes, (*c*) phase path recorders, (*d*) records of mean intensity of echoes, an extensive investigation has been made of night-time echoes ascribed to reflections from gross horizontal irregularities in the F layer, at some distance below the maximum ion density. These irregularities have dimensions up to 100 × 300 km. This effect appears to be confined to a zone of geomagnetic latitude 20°-40°. Correlations with other F phenomena have been established; correlations with E*s* phenomena have been sought unsuccessfully. There is no evidence of correlation with magnetic K indices, but there is a possibility of local correlation with minor magnetic disturbances.

The occurrence of duplication of penetration frequencies and diffuseness of the upper part of F trace have been investigated and evidence adduced of smaller irregularities near the F layer maximum.

2. — *Ionospheric drifts*

Systematic drift observations, by study of the fading in spaced receivers, have been made monthly over an eighteen-month period and the general character of drifts in the night-time F and E*s* and daytime E layer have been established.

3. — E*s layer*

Further studies have been made of characteristics of the Brisbane E*s* layer, its diurnal and seasonal height distribution, apparent thickness and its degree of roughness. Movements of clouds have also been followed, using the direction-of-arrival equipment, and compared with drifts deduced from fading observations.

4. — E *Region tides*

Amplitude and phase of lunar tides in E regions have been determined for Brisbane.

5. — *Ionospheric reflection coefficients*

Some preliminary data on F reflection coefficients at Brisbane have been obtained.

6. — *Whistler recorders*

Observations on whistlers have been made in Brisbane, Hobart and Macquarie Island. Whistlers are more frequently observed in Hobart than in Brisbane ; in summer in Brisbane the general level of (ordinary) atmospherics is high enough to render difficult the recording of whistlers. Some preliminary measurements of dispersions have been made.

(iv) University of Adelaide

The relevant fields of research are :

1. — *Wind Systems in the Meteor Region of the Upper Atmosphere*

An automatic combined continuous wave — radar system for investigating winds in the meteor region of the upper atmosphere (Robertson, Liddy and Elford, 1953 ; Elford and Robertson, 1953) has been used systematically during the last three years to elucidate the structure of the wind systems, their variation with height and their seasonal dependence, from the location of the phase centres and speeds of drift of the meteor trails with the wind.

By Fourier analysis it is shown that the total wind comprises only three constituents of any importance :

(*a*) a prevailing wind ;

(*b*) a periodic rotating wind with period of 24 hours ;

(*c*) a rotating wind with a period of 12 hours.

In the latitude of Adelaide (34°57′ S ; 138°32′ E) these constituents possess comparable amplitudes.

An account of what has been deduced concerning the height and seasonal dependence of these winds has already been given (I.G.Y. Instruction Manual n° 5 Volume III).

It may be mentioned that little evidence has been found for the existence of persistent turbulence in the atmosphere in the meteor region.

A modified form of meteor-wind equipment has been designed and built (W. G. Elford and E. L. Murray) for operation in Antarctica and is now at Mawson (67°36′ S ; 62°53′ E).

It is proposed to measure winds in other latitudes in order to ascertain the global pattern of these winds.

2. — *Analysis of Observations of a remarkable twilight meteor train formed near Adelaide*

(*J. S. Mainstone*)

On February 15th, 1957, at 19.55 hours a spectacular twilight meteor train appeared over Eyre Peninsular, near Adelaide, South Australia.

The circumstances of the appearance were fortunate in that it has proved possible to deduce some useful information about the upper atmosphere.

(*a*) The train was sunlit for some twenty minutes although the ground was in darkness, consequently the train was observed by many people, some as far away as 400 miles. One observer fixed the position of the train in relation to the stars and a pilot of an aircraft flying a known course noted that the train lay almost exactly along his bearing. Thus it was possible to locate the position of the train in plan and orientation with good accuracy.

(*b*) The upper portion of the train remained relatively undistorted whereas the lower portion rapidly became twisted. A good photograph showing this phenomenon was taken by an observer at Port Augusta.

(*c*) By good fortune the earth's shadow was observed by Mr. Mainstone end others to creep along the train allowing the height above the ground of different portions of the train to be deduced.

The following facts were deduced : The visible train was about 180 kilometres in length its top lying at 90 kilometres above the ground and its end at 40 kilometres. The meteor entered the atmosphere at an angle of about 15° to the horizontal and moved ENE to WSW. The motion in its orbit has been direct and about 20° to the exliptic. A significant deduction was that the

point of transition of the distorted to the undistorted appearance lay at a height of 75 kilometres, which agrees with the position of the minimum of temperature. This visible demonstration of the absence of large scale turbulence above 75 kilometres in the meteor region where temperature increases with height is consistent with what has been found by the radio wind studies described in 1.

3. — *De-modulation of a radio wave in the ionosphere*

An investigation of this phenomenon has been carried out by G. J. Aitcheson and G. L. Goodwin (1955). It was established :

(*a*) that demodulation occurred with a carrier frequency of 1550 kc/s (local gyro-frequency 1600 kc/s),

(*b*) was not detectable with 730 kc/s,

(*c*) over a range of modulation frequencies 0-3000 c/s the demodulation increased progressively up to a frequency of about 1000c/s and diminished thereafter when reflection occurred in the F region. When reflection occurred in the E region this frequency dependence was not so evident,

(*d*) there are difficulties in regarding the phenomenon as a manifestation of radio wave self-interaction although a qualitative analysis (Aitcheson, 1957) shows that the frequency dependence of the demodulation is consistent with the view that the seat of the demodulation is the E region.

(v) Universities of Sydney and New England

With the cooperation of Professor J. M. Somerville and Messrs. R. A. Smith, F. H. Hibberd and K. Landecker of the University of New England a 250 kW radio pulse transmitter of gyro-waves has been constructed at Armidale and is nearly ready for operation and test.

It is planned to use this transmitter in the experiments on gyro-interaction which we have been conducting for a number of years. These experiments throw light on the physical conditions in the lower ionosphere particularly the magnetic field and the electronic collision frequency.

The theory of self-distortion of a wave in the ionosphere has also been further developed.

Further work has been done on certain new methods for calculating the coefficent of reflexion of waves by an inhomogeneous medium. The second-order iterations previously published have been generalised to iterations of any higher order and this work has been linked up with the theory of integral equations and the classical method of perturbations. This work is connected with studies of the reflection of long waves by the D region of the ionosphere.

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Canada

Nº 186. — Report of the National Commission III

Since the XIth General Assembly ionospheric research in Canada has continued to be concentrated largely at the Radio Physics Laboratory of the Defence Research Board, at the University of Saskatchewan and at the National Research Council.

The work of these three research centres in the field of ionospheric radio physics is summarized separately below.

Some of this ionospheric research is also being reported to U.G.G.I. because of its general geophysical interest.

Separate reports on the Canadian Geophysical Year program are also available.

References listed include published papers only. A number of institutional reports are available on request in restricted quantity.

Radio Physics Laboratory, Defence Research Board, Ottawa

1. — *Ionosonde Measurements and Predictions*

In January, 1957, monthly publication of Canadian ionosonde data, including daily plots from five stations, was begun.

The prediction service, reported to the XIth General Assembly, has been continued and checked against oblique incidence soundings.

For the Geophysical Year nine additional stations equipped with simple new automatic ionospheric recorders are being operated.

2. — *Oblique Incidence Ionospheric Soundings*

For many years it has been recognized that the technique of ionospheric sounding by means of vertically directed radio waves does not provide enough information to describe completely the physical distribution of ionization in the ionosphere. Several methods are now being used to supplement the vertical incidence recordings.

A method has been developed which permits the examination of the ionosphere by means of radio waves which are incident obliquely on the ionospheric layers. The equipment is similar to the normal sweep frequency pulse sounder except that the transmitter and receiver are separated by a distance of several thousand kilometres, the necessary timing being provided by accurate clocks. This technique has been used over a number of paths in Canada (Cox and Davies, 1955 ; Chapman, Davies and Littlewood, 1955).

Oblique incidence soundings will be begun in 1957 between Ottawa and Slough, England, and between Resolute Bay and Winnipeg, with additional receivers situated at Churchill, Baker Lake, and at Alert, on northern Ellesmere Island.

3. — *Absorption*

Studies of the ionization existing in the lower ionosphere have been carried out by means of absorption measurements. By studying the statistical occurrence of polar radio blackouts at a large number of stations in Canada, Cox and Davies (1954) have found that this type of absorption occurs most frequently in the morning and that the time of maximum occurrence increases with increasing latitude. Detailed studies of the absorption recorded at one station by a vertical incidence pulse recorder have been made by Davies and Hagg (1955). They found that the seasonal variation of noon-time absorption showed very little dependence on the solar zenith angle. On the other hand, there was a pronounced correlation between night-time ionospheric observations and magnetic K index for values of K greater

than 4. The absorption suffered by radio waves of extra terrestrial origin in passing through the lower ionosphere has been studied by G. C. Reid. At frequencies close to 30 Mc/s intense absorption has been observed at times coinciding with local auroral activity. This evidence, together with that obtained from meteor reflections (Forsyth and Vogan, 1957) seems to indicate that the ionization associated with auroral displays is sufficiently intense at heights of the order of 100 km to cause severe attenuation of radio waves at frequencies up to at least 50 Mc/s. Intense absorption of low frequency radio waves in the lower ionosphere at the time of the intense solar flare of February 23rd, 1956 was reported by McKerrow (1956) for a station on the dark side of the earth. The onset of absorption seems to have been correlated in time with an increase in cosmic ray activity associated with the solar flare.

4. — *Lunar Tide*

The variation in height of the E-region ionization under the influence of the lunar tide has been studied at Ottawa (Littlewood and Chapman, 1955). These measurements suggested that the phase of the lunar variation was similar to that observed in Australia and nearly opposite to that observed at Cambridge. More recent measurements seem to indicate that phase reversals may occur at Ottawa lasting for periods of several months.

5. — *Travelling Disturbances*

Motions of inhomogeneities in the ionosphere as observed by vertical incidence recorders have been studied by Hagg and Hansen (1954). They found three distinctive types of motion. One type appeared to be due to a motion of moderate velocity (800 km/h.) in the E-region. The second type was ascribed to vertical motion of discontinuities downward from the F2-region to the E-region. The third type consisted of extremely rapid motions (up to 1500 km/h.) in the E-region. In the course of theoretical studies of wave-like motions, Hines (1955*a*, 1956*a*) has found characteristics associated with an electron resonance phenomenon which appeared to be similar to those of the large scale travelling disturbances which have been observed in the ionospheric F-layer.

6. — *Radio Star Scintillations*

The radiation from a radio star in Cassiopeia has been recorded continuously for a period of three and a half years. Studies of the fluctuations of the received energy, suggest that the characteristics of these scintillations as observed in Canada are significantly different from those observed at lower geomagnetic latitudes. At least part of the scintillations may be associated with auroral and geomagnetic disturbances (Hartz, 1955*a*). The recent study by Reid suggests that the rate of scintillation may be used to study the direction of motion of the ionic inhomogeneities responsible for the scintillations. The relationship between solar radio events and associated disturbances in the earth's upper atmosphere have been studied by correlating the various observations mentioned above with radio observations of the sun (Hartz, 1955*b*). The evidence suggests that at least certain types of auroral disturbance are preceded by recognizable solar radio events.

7. — *Meteor Ionization*

The ionization produced in the upper atmosphere by meteors has been studied by radio methods. A new technique in which the receiver is located at a distance of several hundred km from the transmitter has been explored (Forsyth and Vogan, 1955). The relationships which exist between the orientation distribution of the incident meteors and the number of signals observed by this method have been the subject of extensive studies by Hines and others (Hines, 1955*b*; Forsyth, Hines and Vogan, 1955; Hines, Forsyth, Vogan and Pugh, 1955; Hines, 1956; Pugh, 1956*b*; Hines and Pugh, 1956; and Hines and O'Grady, 1957). The diurnal and seasonal variation of meteor rates has been investigated by Vogan and Campbell (1957) who found a large variation in the day-to-day signal rates and also concluded that the presence of a small amount of absorption could modify appreciably the observed diurnal variation. The hour-to-hour variation in the intrinsic strength of the Quadrantid meteor shower has been investigated by Hines and Vogan (1957). This study has demonstrated the value of the forward-scatter technique for measurements of this kind. Detailed studies of the amplitude and fading characteristics of individual meteor signals have also been carried out

with a view to determining the wind motions and wind shear existing at meteoric heights in the atmosphere. Measurements of the durations of forward-scattered signals from meteor trails (Forsyth and Vogan, 1956) have revealed a striking difference in duration between signals observed on north-south and east-west paths. This difference may possible be due to the influence of the earth's magnetic field on diffusion at meteoric heights.

8. — *Auroral Ionization*

The relative amplitudes of signals reflected at 4 frequencies from auroral ionization have been measured over a forward-scatter path 1000 km in length (Forsyth and Vogan, 1957). The relative variation in amplitude suggests strongly that at frequencies up to 50 Mc/s the reflections arise from regions where the ionization is sufficiently dense to cause total reflection. In order to assist with these studies of auroral ionization a simple radar system, working on the FM principle, has also been built. The equipment which uses a transmitter radiating only a very few watts, has enough sensitivity to record the occurrence of most visible auroral displays. Both range and doppler information is obtained. Records produced by this equipment during the second half of 1956 are being studied in conjunction with magnetic records and the records obtained from the forward-scatter paths.

Recent measurements on 500 Mc/s with 28-foot antennas and 10 kW average power show extremely strong echoes from auroral regions where the radar beam is nearly perpendicular to the direction of the magnetic field.

Some observations have been made at frequencies in the 30-50 Mc/s range which seem to indicate that the aurora emits radiation at these frequencies (Hartz, Reid and Vogan, 1956).

9. — *Whistlers*

Very low frequency radio waves which arise from thunder storms and are propagated along paths which reach to the far outer regions of the earth's atmosphere have also been studied. It is hoped that these signals, known as « whistlers », will give new information concerning the composition of the earth's atmosphere out to distances of two or three earth radii. It has been

deduced by Storey (1956) that it should be possible to detect the presence of ionized hydrogen in these regions by careful examination of whistler spectra.

10. — *Lunar Radar Echoes*

Early in 1957, measurements of lunar echoes were begun, using 10 kW average power on 500 Mc/s with separate 28 foot transmitting and receiving telescopes. Preliminary results indicate a rotation of the plane of polarization of the order of one or two complete revolutions.

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THE UNIVERSITY OF SASKATCHEWAN, SASKATOON

1. — *General*

The investigations at Saskatoon (52.1° N ; 106.6° W) include spectrographic studies of the emissions from the polar aurora, and from the twilight and night airglows ; correlations between auroral phenomena and magnetic and ionospheric disturbances ;

experimental studies of the inhomogeneities in the ionosphere (particularly during auroral displays), by reflecting radio waves from aurora, and by continuous observations on the scattering of radio waves and of the scintillations of the 50 Mc/s waves from the radio star in Cassiopeia ; and the morphology of auroral displays over West-Central Canada. The observational program has been expanded in the past two years to include the operation of all-sky, auroral cameras at Flin Flon (54.7° N ; 102.0° W), Meanook (54.6° N ; 113.3° W), and Uranium City (59.6° N ; 108.8° W) ; and electronic, flux-gate type magnetometers at Flin Flon, and Swift Current (50.3° N ; 107.7° W). The spectrographic program at Saskatoon is also being integrated with a somewhat similar one established at Churchill (58.8° N ; 94.2° W) by Montalbetti of the Radio Physics Laboratory, Defence Research Board of Canada. It is anticipated that the integrated program will lead to reliable comparisons of the relative frequencies and intensities of various auroral and airglow emissions for a range of latitudes extending from inside to outside the auroral zone of maximum occurrence. The spectrographic and morphological studies are not included in this report but may be found in the 1957 report to U.G.G.I.

2. — *Auroral Phenomena and Magnetic and Ionospheric Disturbances*

The equipment consists primarily of all-sky cameras which take a picture of the sky every minute on 16 mm film (Meek, 1955) ; three component, electronic, flux-gate type magnetometers which are usually operated to give an inch of record per hour (Meek and Hector, 1955) ; an auroral intensity recorder which scans a meridional strip of the sky from the northern to southern horizons at Saskatoon (Hunt en 1956) ; and a standard, automatic ionosonde unit which has been operated on selected occasions at Saskatoon. Visual auroral data (observations taken once each hour) have been available from Resolute and Baker Lake in the Northwest Territories and Churchill, Manitoba. Recently, all-sky camera records of aurora and one-component magnetometer records have become available from Churchill. Much of these data are now being placed on IBM punch-cards to facilitate analysis.

Comparisons of the magnetic and auroral records indicate that whenever aurora is present, the magnetic records are disturbed,

the magnitude of the disturbance depending primarily on the closeness of the auroral display to the magnetic station. There are also occasions without visible aurora when the magnetic records show appreciable disturbance, often lasting for many hours. It appears that whenever aurora is present, effects are produced in the upper atmosphere which result in appreciable changes of the earth's magnetic field close to the aurora.

From auroral, magnetic and ionospheric observations at Saskatoon, Meek divided disturbances into four categories (Meek, 1953 ; Meek and McNamara, 1954).

Variations of the earth's magnetic field were examined using data of the Polar Year 1932-33 (Meek, 1955). It was concluded that the auroral zone takes the form of two opposing Stormer-like spirals, one due to positive-particle precipitation and the other to negative-particle precipitation. These intersect at a high latitude at about 10 a. m. local geomagnetic time and at a lower latitude at about 10 p. m., and move around the earth with the sun. Support for this conclusion, based on observed characteristics of aurora, is dependent on further observations from auroral stations during the International Geophysical Year.

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3. — *Studies of Ionospheric Inhomogeneities*

The equipment consists of two radar units operating on 106 and 56 Mc/s respectively, and with their antennas mounted on a rotatable tower so that both beams scan simultaneously the same part of the sky ; a 200 Mc/s radar with a fixed antenna ; an interference type of radio telescope for detecting the 50 Mc/s radio waves from the strong source in Cassiopeia ; and receiving equipment to record the scatter from inhomogeneities in the ionosphere of radio waves transmitted between selected points in Western Canada.

An attempt is being made to correlate the occurrence and

characteristics of echoes with data on auroral and magnetic disturbances obtained from all-sky cameras and magnetometers operating at Saskatoon, Flin Flon, and Churchill, and from patrol spectrographs operating at Saskatoon and Churchill. The majority of the auroral echoes occur from the region in the direction of Flin Flon and Churchill. Typical auroral echoes are occasionally observed from regions where the angle between the incident radio waves and the auroral structures (assumed parallel to the lines of the earth's magnetic field)departs notably from 90°.

A pulsed double-Doppler radar technique was used to study the 90.7 Mc/s signals reflected from auroral ionization (McNamara, 1955). A spectrum analyzer was used in conjunction with the radar to measure the power spectra of the auroral echoes. The Doppler data were compared with observations of visible aurora and with simultaneous echoes on the 56 and 106 Mc/s radar units. Most of the reflected signal appears to come from almost stationary targets, or from targets moving collectively in range.

Notable variations in the polarization of radio echoes from aurora have been observed, using frequencies of 56 and 106 Mc/s (McNamara and Currie, 1954). Observations on 56 Mc/s showed a large variation of the polarization ratios, a large portion exhibiting a strong degree of de-polarization. Observations on the same frequency for circular polarization showed approximately equal amplitudes for left and right-handed senses for rotation. The polarization ratios (horizontal to vertical) sometimes differed widely for echoes occurring simultaneously but at different ranges. Also the polarization of the echoes was observed at times to change from the plane to the de-polarized state, or vice versa within a period of minutes. All the observations of the polarization of 106 Mc/s echoes showed only plane polarization in the same sense as the transmitted signals.

No significant relationship has been discovered between the amplitudes of the scintillations of the radio star in Cassiopeia and the occurrence and position of aurora.

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Upper Atmosphere Research Section, National Research Council

In 1954 there was established in the Radio and Electrical Engineering Division an Upper Atmosphere Research Section. It is intended that this group will study fundamental aspects of upper atmosphere phenomena. Up to the present time a large part of their effort has been directed toward preparations for the International Geophysical Year; although some studies have been carried out in the fields of meteors and aurora.

Radar recording of meteor echoes during the active periods of the major annual showers has been continued on a frequency of 32 Mc/s. This work has been carried out in cooperation with visual and photographic recording and has been part of a combined Dominion Observatory NRC study of meteors. Special meteor radar equipment in the same frequency range, designed to give a constant level or performance, is being prepared for continuous operation during the I.G.Y.

Detailed study of the so-called « head echoes » received from two meteors has been carried out by McKinley who concludes that while the diffraction phenomenon may explain the observed effect for faint meteors, for the bright meteors the head echo is produced by a « moving-ball » type of target (McKinley, 1955*a*). McKinley has also determined by radio methods the orbit of the Eta Aquarid meteors (McKinley, 1955*b*). An unusual Perseid meteor, observed by means of 3-station radar measurements, has been used to determine the drift of ionization, at meteoric heights and the variation of diffusion with height (McKinley, 1956*a*). A study of the factors affecting the radio determination of meteoric velocity has led to the conclusion that such determinations are not subject to gross systematic error as might be inferred from a comparison of optical and radio results (McKinley, 1956*b*).

A relation between radio echo duration and visual magnitude of meteors has been established by Millman and McKinley (1956) on the basis of some three thousand three hundred individual observed meteors. They conclude that a meteor of absolute magnitude + 5 produces 2×10^{12} electrons per cm of its path. Simultaneous measurements of the back and forward-scatter signals from individual meteors made by McKinley and McNamara

(1956) have indicated that while the duration of the forward-scatter signal is larger than that of the corresponding back-scatter signal the enhancement is not as great as would be expected on the basis of simple theory.

The distribution of visual magnitudes for a large number of meteors observed in a program which started in 1933, has been determined by Millman and Burland (1957). The ratio of numbers of meteors observed in successive magnitude classes was found to be substantially larger than expected on the basis of previous work. The present state of meteor theory has been summarized by Millman (1956).

Auroral radar echoes have been recorded on a 50 Mc/s on a continuous basis at Ottawa since April, 1955. Four identical transmitting-receiving units have been constructed and will be operated throughout the I.G.Y. at Resolute Bay, Baker Lake, Saskatoon and Ottawa. The number of occasions on which auroral echoes have been observed at Ottawa is substantially greater than might be inferred from the standard charts of visual auroral occurrence. The use of standard radar techniques and doppler techniques for auroral measurements has been discussed by McNamara (1956).

In addition to the radio observations which are planned during the I.G.Y., preparations have been made for visual and photographic observations of aurora. An all-sky camera has been designed and 9 units have been constructed. This camera differs from others which are currently in use, in that it uses 35 mm film in order to improve definition. Alternate exposures have durations of 40 sec. and 4 sec. in order to accommodate the wide range of auroral intensity and motion

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Czeckoslovakia

N° 172. — Report of the National Committee to Commission III

Theoretical Studies

Theoretical researches undertaken in Czechoslovakia in the field of the Ionosphere have been principally made at the Astronomical Institute, Ondrejov.

The electronic density profiles (i. e. according to height) have been computed (1, 2, 3), account being taken of the fact that only a well defined part of the incident photon's energy is used by the photoionization process, the rest of this energy being transferred as kinetic energy to the dissociated particles. Thus, the resulting increase of temperature at the maximum of ionization must cause a rarefication of the gases and of ions and electrons as well. Into this dilute atmosphere, owing to heating, the ionospheric layer may be split in two parts.

This theory led to a unique formula (4, 5) defining the diurnal behaviour of the critical frequency ; this formula is valid for any geographical location and any seasonal and solar circumstance. A method apt to quickly predicting the optimum conditions for short wave communications resulted from this conclusion.

From an analysis of the parameters of this formula, other properties of the F-layer have been found (6,7).

A formula has been developed in view of predicting the solar effects on the ionosphere (8, 9).

Researches concerning the wave propagation paths from cosmical radiosources are indexed amongst the reports of Commission V (10, 11). However, a short study (12) on meter wave length propagation around the Earth at long distances is not without interest for long distance radiocommunications. From this study a radio wave can perpetually propagate itself along the lower part of an ionospheric layer, as long as the layer structure remains unmodified. A change in this structure leads to a propagation accompanied by an oscillation of the wave between two neighboring levels. A larger change in this structure, or a more ionized cloud, may cause the wave to be shifted from the horizontal direction and reach the ground surface. This long distance propagation around the Earth may theoretically exist in a wide spectral domain extending from the longest wave lengths to eigth times the critical frequency.

The investigations on the E layer led to define its diurnal and seasonal variation, as well as the effects exerted on it by the meteors (13, 14, 15, 16).

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France

N° 220. — Report of the National Committee to Commission III

(Translation)

Ionospheric soundings

According to a general reorganization of ionospheric researches and studies in France the S.P.I.M. was dissolved on January 1, 1956. From this date, its facilities were placed at the disposal of the « Centre National d'Etudes des Télécommunications (CNET) ». The research group of SPIM at Neuf-Brisach was dissolved on July 1, 1956. The work previously made at Neuf-Brisach is now carried out at the national prediction centre of Saclay.

The sounding stations listed at the General Assembly of the Hague (1954) pursued their hourly observations, except the Nha-Trang station which interrupted its activity from the second quarter of 1956. On the other hand the station in Terre Adélie has been re-established in 1956 and will normally continue its

observations up to January 1959. The Bangui and Tamanrasset stations were re-equipped and a station was planned for I.G.Y. in Tahiti. Panoramic sounders are now sent to Bangui, Tamanrasset, Terre Adélie, Kerguelen and Tahiti.

The results published before 1956 in the information bulletins of SPIM-O and the « Bureau Ionosphérique Français » will henceforth be gathered in a unique « *Bulletin d'Information Ionosphérique du C.N.E.T.* ».

Predictions for radio propagation

Ionospheric predictions are now made with two electronic computers and punched card methods. Major improvements resulted from this technique.

Predictions extending upon a geographic area having a radius of 6000 km are regularly made for Paris and Dakar. A global computation method based on graphs for determining the MUF at distances larger than 10 000 km, account taken of the ionization in the F2 and E*s* layers, has been proposed by B. Cagnac. A first comparison between the prediction methods of C.R.P.L. (Circular n° 462) and SPIM has been made by the same author (6) ; it was shown that large discrepancies may occur for the MUF and that, for the LUF, systematic discrepancies of great importance are due to decays by energy-spreading with distance, in the absence of absorption.

A new representation of the longitude effect in the F2-layer has been proposed by Delobeau (9). As a consequence, it was shown that the actual distribution of ionospheric stations (essentially continental) is not convenient for ionization mapping.

The solar eclipses of June 1954 and December 1955 were observed respectively in Bergen and Djibouti.

Experimental verifications

Radio propagations were investigated on various paths from North-American Loran systems in Dakar, and from Freiburg fixed frequency transmission in Rabat and Dakar.

Ionospheric scatter propagation on 51.3 Mc/s was studied between Kootwijk (Netherlands) and the south of France (Toulon and Nice). A trial on a ship in the Mediterranean Sea showed the possibility of a reception up to North Africa.

Studies on Ionospheric absorption

A measuring equipment for ionospheric absorption has been put in regular use at Domont in 1955. A circularly polarized antenna allows to discriminate the magneto-ionic components of the signal after reflection by the ionosphere ; the amplitude of these echoes is recorded continuously. Such measurements are made regularly on 3, 4 Mc/s, two days a week (hourly, in day-time). During two years, they were made at intervals of 15 minutes several days a week. Night-time measurements are also made for comparing the amplitudes of echoes when non-selective absorption is weak, with these amplitudes in daylight conditions. A detailed study of the results obtained from 1955 is now undertaken (4).

A new instrumentation was devised by R. Chezlemas (5) for equipping I.G.Y. absorption-measuring stations. This apparatus allows simultaneous recording of two echo-amplitudes on fixed frequencies (2.1 and 3.4 Mc/s) ; these echoes are electronically selected, and recorded on a logarithmic scale calibrated in db. Such an equipment will be operated during I.G.Y. at Champfleury, Kerguelen, Bangui, Tamanrasset, and Tahiti. Methods of measurement and scaling have been studied in accordance.

Ionospheric drifts

Previous investigations on ionospheric drifts have been pursued in Domont, using the three receivers method. The aerials separated by about 200 m on rectangular baselines are operated on 3.4 Mc/s. Two-hourly records have been obtained from March 1956, several days-each week, in day-time. A few observations only were made during night-time. The reduction method has been analysed and will be published shortly. The apparatus has already been described (see Ionospheric absorption). Several similar stations will be operated during I.G.Y.

Ursigrams

A new building has been erected in Bagneux, part of it was affected to the Service of Ursigrams. Solar pictures are now received from Meudon Observatory by a fac-simile system. The number of data received or sent by the Service, was considerably

increased owing to the fact that several Western European countries joined to the list of participants. Short term predictions, improved by this organization, were continued on the basis of more numerous data.

THEORETICAL PROBLEMS OF IONOSPHERIC PROPAGATION

Argence, Rawer and Suchy (3) have shown that, if a general equivalence theorem is obtained from the propagation equation, the theorem of Martyn may be deduced from it under general assumptions. Strong absorption may be studied on the basis of dispersive media and metallic reflection theories.

MAGNETO-IONIC THEORY AND RESULTS

Several publications and a Doctor's Thesis of D. Lépéchinsky (see bibliography) investigate the behaviour of electromagnetic wave propagation characteristics in an ionized medium under the simultaneous influence of the geomagnetic field and the collisions between electrons and neutral molecules ; this theory is based on the general magneto-ionic formula of Appleton-Hartree. After having established a convenient method for computing the parameters (refraction and absorption indices, polarization ellipse) the author shows that a transition level occurs in the ionosphere at an altitude depending on the collision frequency and the geomagnetic dip ; below this level, the propagation has a quasi-longitudinal character (Q. L.) ; above the transition level, this character is quasi-transverse (Q. T.). Particular configurations occur as a result on the normal E-trace in the ionograms (hooks, inflection points, hollows) ; these configurations, already encountered, stood either unexplained or were attributed to sporadic E. An important consequence of the Q. L.-propagation, responsible of such configurations, is the modification imposed to the conventional value of the maximum electronic density in E-layer :

$$N = 1.24.10^4 \ (f_c^2 + f_c f_H) \text{ instead of } E = 1.24.10^4 \ f_c^2$$

Computing the absorption index, Lépéchinsky gives an evaluation of the attenuation for both magneto-ionic components in the D-region, for various collision frequencies and wavelengths, and for dips in the interval 0-90°. The curves obtained show clearly a different influence, upon the absorption index for one component or the other, of the angle between the wave-propagation vector

and the geomagnetic field. Consequently, the inadequacy of a simple cosine-law for oblique incidence computations is readily shown.

If the propagation vector and the geomagnetic field are orthogonal, both components (ordinary and extraordinary) have practically the same absorption indices. As a consequence, the correct MUF are those of the extraordinary mode on E-W propagation paths.

Reflection coefficient on ionospheric layers

P. Poincelot achieved an important work on the reflection coefficient determination, in the cases where the electronic density distribution with height is linear or exponential. This work was recently completed by a study of the case of a parabolic distribution.

In the first cases, the reflection loss varies very rapidly with the collision frequency and the ionization gradient. This loss may attain 20 db at 3.4 Mc/s for a collision frequency of 10^5 sec.$^{-1}$ and an electronic density gradient of 3.10^4 el.cm^{-3} km. In the same conditions, this loss falls to 7 db when the gradient is 7.10^4 el.cm^{-3}.km.

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Germany

N° 192. — Report of the National Committee to Commission III

by W. Dieminger

Chairman, Committee III of the German National Committee

1. — Meetings

The Commission participated in three scientific meetings held jointly by the Arbeitsgemeinschaft Ionosphäre and the German National Committee of U.R.S.I. at Kleinheubach on 28/30-10-54, at Tübingen on 19/22-10-55 and at Kleinheubach on 10/13-10-56. Papers presented at these meetings were printed in separate volumes which may be obtained in a limited number from the Secretary of the German National Committee, Dr. H. Fleischer, Darmstadt, Rheinstrasse 110.

Another meeting of interest to the Commission was held by the Nachrichtentechnische Gesellschaft, subgroup on Wavepropagation at Frankfurt on 13-9-56.

2. — Ionospheric observations

a) Pulse observations

Routine sweep-frequency records and absorption measurements are being made at the following locations :

Juliusruh/Rügen	54.6° N	13.5° E
Lindau/Harz	51.65° N	10.13° E
Breisach	48.1° N	7.8° E

The station at Neuershausen operated by SPIM since 1946 has been transferred to Breisach after the dissolution of SPIM,

and is sponsored now by Fernmeldetechnisches Zentralamt der Deutschen Bundespost.

Wind measurements are being made at Juliusruh, Köln and Breisach.

During the I.G.Y. a temporary station will be operated at Tsumeb, Southwestafrica, 19.14° S ; 17.43° E. Routine sweep frequency records, absorption measurements on short and medium wavelength and observations of geomagnetic variations will be made after 1-7-57. During the second half of the I.G.Y. pulse transmission on fixed frequencies between 10 and 35 Mc/s will be carried out between Lindau (transmitter) and Tsumeb (receiver). A second temporary station will be operated jointly with the Finnish Academy of Science at Södankyla 67.5° N 26.5° E. A sweep frequency recorder with 50 kW peak pulse power will be used both for vertical and oblique incidence measurement (Södankyla-Lindau 2000 km).

b) Continuous wave observations

Routine field strength records on 1178, 272, 245, 185, 120 and 16 kc/s are being made at Kühlungsborn. Absorption values are derived from the records on 1178 and 245 kc/s. Simultaneous observations on 245 and 272 kc/s are carried out at Leipzig and Prag.

Routine field strength records are being made at Lindau/Harz on 2,05, 2,6 and 6,3 Mc/s over distances of 200-300 km, for intercomparison with vertical absorption measurements.

3. — Prediction service

Basic predictions of radio propagation conditions for a number of circuits are being issued two months in advance by Fernmeldetechnisches Zentralamt der Deutschen Bundespost (6, 7, 9, 11, 48). Short term forecasts are being supplied two times per day (day and night) to the users by teleprinter. These short term forecast are based on current observations of short-wave long-distance circuits, geophysical and solar data. Short term forecasts are given in terms of the « Bandkennziffer ». The Bandkennziffer is defined as a number proportional to the bandwidth of the useful frequency range and to the mean fieldstrength within that range, for a fixed circuit (for instance Europe-Northamerica).

4. — Reduction of ionograms

To get a more competent picture of the ionosphere it is proposed to classify the ionospheric layers according to their thickness. The intensity of the reflections must be taken into account to derive the exact critical frequency of a thin layer. Partial reflections cannot be neglected. Proposals are made for more generally applicable definitions of the « descriptive letters » (19).

For the critical frequency of the F1 layer a better definition is attempted (56). Owing to the complex structure of the F1/F2 layer the values deduced directly from ionograms have no straight forward relationship to solar influx. The correction to be applied depends on the theory of production of the F2-layer.

A method for a rapid reduction of virtual heights to true heights was worked out (2, 3, 5). It is based on Bookers method, however including the influence of the magnetic field of the earth. It is applicable to parabolic, cosine and Epstein layers. An extension to more complicated electron distributions is in progress. It was found that the extraordinary component is more suitable for reduction then the ordinary one.

A method for automatic determination of the MUF was worked out (21) at Neuershausen. The ionogram is superimposed to a reciprocal transmission curve by electronic means giving a direct record of the MUF.

5. — Absorption

A method for continuous recording of the amplitude of echoes was developed at Lindau (47). An electric gate was used for selecting echoes of different order, and the amplitudes were recorded on a logarithmic scale. It was found that the variation of the reflection coefficient with time of day exhibits considerable interdiurnal variations and is not proportional to the zenith angle of the sun. That result proves that measurements only at noon are not always representative for the average absorption of individual days. Focussing effects due to ripples in the ionosphere were found to be the most important cause of errors in absorption measurements. Because of the difficulties in the reduction of the records and in the maintenance of the logarithmic calibration the system was abandoned in 1956. With the new scheme the amplitudes of all the echoes are displayed on an A-scope with a linear scale, the sensitivity of the receiver being switched

over in powers of ten in a cyclic manner. Snapshots are taken every ten seconds automatically and pictures are selected where the amplitude of the wanted echo falls within the linear range of the A-scope. A polarimeter is used to separate o and x components. The transmitting antenna is a delta supported by a 60 m mast. Using a peak pulse power of 10 kW that installation gives reflections down to 1 Mc/s even at noon.

Theoretical work on focussing effects revealed that focussing and defocussing does not compensate each other. As a matter of fact the value of the apparent reflection coefficient will be shifted to higher values by focussing. A correction must be applied to get the correct values (51, 55, 60).

The results of absorption measurements at Dakar from 1951 to 1954 have been analyzed for deviative and nondeviative absorption (25). For both components a variation with sunspot cycle was found. It is concluded that the electron density in the D layer increases proportional to the sunspot number. For the E layer the collision frequency at the maximum of the layer appears to increase with decreasing sunspot number. It is thought that that is caused by a decrease of height of the maximum of the layer.

At Lindau the diurnal variation of nondeviative absorption is being derived from fieldstrength records on 2,05 and 2,6 Mc/s using statistical methods of evaluation. Preliminary values are being published in « Ionosphärenbericht » (38) every ten days.

The stations at Lindau and Neuershausen participated in the Absorption Intercomparison Experiment.

The results of fieldstrength observations at Kühlungsborn on medium and long wavelengths may be summarized asf ollows (43, 44, 61).

(a) The daily and the seasonal variation of the absorption on medium and long wavelengths cannot be represented by a uniform $\cos^n\chi$ law. On long wavelength and for large zenith angles of the sun holds $n = 1$, for small zenith angles $n = 0{,}5$. On medium wavelength the value of n varies seasonally between 0,75 and 0,5.

(b) The scatter of individual absorption values at noon is independent of the season for medium wavelength (± 4 db); it is greater in winter (± 4 db) than in summer (± 2 db) for long wavelength.

(*c*) For the same zenith angle of the sun the absorption is larger in summer than in winter. It is concluded that the structure of the lower ionosphere varies basically with the season.

(*d*) From observation during the eclipse on 30-6-54 it is thought that the lower ionosphere has a complicated and multiple structure.

(*e*) The effects of solar corpuscules in the lower ionosphere are closely correlated to the geomagnetic activity. From the time of occurrence of those effects it is concluded that in medium latitudes the corpuscules will not penetrate generally to heights below 90 km whereas a height of 95 km will be reached regularly. These effects spread from the polar zone towards the equator with an apparent velocity of approximately 180 km/h.

(*f*) Using data from Huancayo, Watheroo, Kochel, Freiburg, Dakar and Slough it has been found (33) that in the formula for the critical frequency of the E layer :

$$foE = K \cos^n \chi$$

both K and *n* vary by approximately 1 % with the phase of moon.

Lunar tidal variations of midday critical frequencies of the F2 layer at Slough for the period 1942-1955 and of lowest night time critical frequencies of the F2 layer at Lindau for the period 1948-1956 were analyzed (42). The semi-monthly period of the former amounts to 1 %, and that of the latter to 2 %. The amplitude is much smaller than for stations in the equatorial belt. The maxima of the tidal variations of the noon values at Slough occur two days after full- and new-moon respectively, the maxima of the tidal variations of lowest nighttime values at Lindau exactly on full- and new-moon respectively.

6. — Movements in the ionosphere

Ionospheric drift observations were continued at Neuershausen and Köln (32, 45) using the Krautkrämer-Mitra (spaced receiver) method. The station at Neuershausen participated in the Drift Intercomparison Experiment. Generally it was found that the dispersion of values of velocity and direction is not as large (16, 34, 35) as assumed in theoretical work (15, 49). Observations of drift in the E layer carried out at Neuershausen yielded a clockwise rotation of the wind vector by approximately 30° per hour during daylight. The velocity ranges between 30 and 200 m/sec with

an average value of 80 m/sec. Average velocity seems to be higher in winter (36).

Ionospheric drift observations on medium wavelength are being made at Kühlungsborn recording the fieldstrength of the broadcast transmitter Kalundborg on 245 kc/s with three spaced receiver (base length 600 m).

Using high speed panoramic equipment apparent vertical movements were observed appearing in the F2 layer first and vanishing in the E-layer. It is thought that a pressure wave or an additional ionizing source may explain the phenomena (17, 53).

7. — Es LAYER

Extensive studies have been made about the irregularities and regularities of the Es layer (52, 54). The correlation of occurrence falls rapidly with increasing distance and equals zero at a distance of approximately 1000 km. In spite of the irregular behaviour of occurrence there is a distinct statistical maximum both of the top frequency and the blanketing frequency. In northern temperate latitudes the maximum occurs between May and August. No distinct influence of solar cycle was found. The geographical distribution shows a pronounced maximum at the magnetic equator.

To understand better the structure of the Es layer, ionograms were classified for transparency, scatter, angle of incidence, and time variation of the layer. It results that the Es layer is a thin layer of a few kilometer thickness for most of the time. A cumulocirrus like structure seems to be appropriate model. Among the different possibilities of origin, ionization by energy stored in the form of dissociated molecules or large numbers of negative ions appears the most probable one.

8. — F LAYER

The decrease of the critical frequency of F1 near the geomagnetic equator found by Gosh, was established by further observations (30). Contrary to that, values of (M 3000) F1 and F1-3000-MUF show an increase of 2-7 % near the geomagnetic equator because the virtual height of F1 attains a minimum there.

Studies of the world wide distribution of (M 3000) F2 revealed

(29, 31) that the influence of the magnetic dip is by far more pronounced during daylight than during night. The nighttime values appear to depend only on the solar influx during daylight. A number of irregularities have been found even for a narrow range of longitudes. A common feature for american stations is an absolute minimum during daylight at the magnetic equator. A pronounced maximum arises at sunrise for all latitudes. A secondary maximum exists during daylight near 40° N. No anomaly of (M 3000) F2 was found near the walls of the equatorial « trough ».

The influence of solar activity upon (M 3000) F2 varies with the time of day, with the season, and with the geophysical coordinates (70). The time of day is the most important factor. A maximum of variation was found in the afternoon.

Studies on statistical relations between the degree of geomagnetic activity and the average deviation of daytime and nighttime critical frequencies of the F2 layer in medium latitudes have been continued (40, 41). The depression of the critical frequency during magnetic disturbances depends on the geomagnetic latitude, the season, and the sunspot cycle. The practical significance of these results was discussed with respect to the prediction of radio communication disturbances.

9. — Meteoric ionization

It has been proved with a high degree of probability that the short living echoes recorded nearly continuously during nighttime on 3-2 Mc/s from heights above 95 km, are produced by minute meteorites. The maximum detecting range of these echoes ought to be proportional to the average influx of meteoric matter. It shows a distinct increase toward the morning hours as predicted by theory. In addition coincidence with typical meteoric echoes on high frequencies was observed.

10. — Oblique incidence experiments

Sweep frequency pulse recording at oblique incidence was carried out between Keimola (Finland) and Lindau (Germany) over a distance of 1320 km for a period of 3 months starting with the eclipse of 30-6-54. The equipment sweeps the frequency

range 1,0-16,0 Mc/s within 8 minutes. Synchronisation of the pulse recurrency frequency and exact tuning is achieved by a pair of crystal clocks (27). The results were compared both with vertical soundings near the midpoint of the trajectory (Ekenäs) and with vertical soundings at Lindau.

The main results are as follows (26, 28, 46).

(*a*) The effect of the eclipse was observed very distinctly on the F1 and F2 paths. It was possible to derive the critical frequency at the reflection point from the oblique incidence records with sufficient accuracy.

(*b*) The observed trace of the high-angle and of the low-angle ray corresponds well to that derived theoretically from vertical ionograms. Major discrepancies were found for the MUF which is shifted slightly to higher frequencies. That is caused by the irregular curvature of the F2 layer presumably.

(*c*) The high-angle (Pedersen) ray is observed over a much wider range of frequencies than assumed hitherto from theoretical considerations. It has been shown recently that the effect of spatial dispersion is compensated by very low attenuation along the path of the high-angle ray (57). The latter seems to play an important role for communication just outside the limiting distance of the single hop path.

(*d*) Weak echoes were observed extending from the MUF towards higher frequencies on approximately 10 % of the time. The origin of these « whiskers » is unknown still.

Pulse transmission on fixed frequencies were carried out between Dakar (Africa) and Neuershausen (Germany) over a distance of 4730 km on 18,6 and 11,4 Mc/s (24). The following paths were observed (according to the frequency of occurrence) : 18,6 Mc/s: 2 × F, 3 × F, 4 × F (rare), E + F (rare) ; 11,4 Mc/s : 2 × F, 3 × F, E + F, 4 × F. The daily variation of occurrence of the different paths has been investigated.

Similar observations were carried out between Laval (France) and Graz (Austria) over a distance of 1200 km on frequencies between 6,3 and 11,3 Mc/s (24). Set-in and set-out time was observed, and the actual MUF was compared with the MUF calculated from the ionogram in the midpoint of the path. The median value of the observed MUF was 8 % respectively 15 % higher than the calculated one for different methods of calculation.

It is presumed that difference is caused by a horizontal gradient of electron density shifting the MUF towards higher frequencies.

Loran systems were observed over distances of 1500 and 7000 km respectively and the occurrence and intensity of the differents paths were evaluated (24).

The deviation of the great circle path has been studied over large distances circuits (39), and a Gaussian distribution of the deviations has been found. The maximal deviations were $\pm$ 3° for 80 % and $\pm$ 5° for 98 % of the observations respectively on frequencies between 13 and 21 Mc/s. The mean value was identical with the true direction for paths to Africa and Southamerica. For the circuit Germany-Japan a mean deviation of 2-3° to the south has been found (polar circuit).

11. — Backscattering

Observations of backscattering using commercial telegraphy transmitter have been continued (8,10,13). The scatter coefficient varies proportional to $\sin^2\theta$ (θ angle of elevation) for angles of elevation between 8° and 36° (12). The scattering loss amounts to —25 db for $\theta = 36°$ and to —80 db for $\theta = 8°$. The angle of incidence of backscatter depends mainly upon the polar diagram of the transmitting aerial.

The gain of a receiving aerial for backscatter is nearly identical with that for long distance reception. It is concluded that the backscattered radiation is a coherent one (14).

Observations of backscatter using pulse modulated broadcast transmitters (73) showed that the maximum range of backscatter echoes depends critically upon the vertical polar diagram of the antenna. The interpretation of the echoes is rendered more difficult if antennas with wide main lobes and bad front to back ratios are used. Most of the echoes can be interpreted by normal ground scatter via the F-layer. In addition echoes from the coast of Greenland and from auroral structures have been observed.

12. — Forward scattering

Fieldstrength measurements and recordings on v. h. f. scatter propagation at 51,3 Mc/s were performed with a 10 kW cw-transmitter and a special receiver of 70 c/s bandwidth between Kootwjik

and Neuershausen (500 km) and between Kootwijk and Toulon (1000 km). The medium propagation loss over free-space propagation ranged between 90 and 100 db for both distances. Short bursts of field strength were caused by meteor trails (22).

Fieldstrength records and teleprinter experiments are being carried out on 42,3 Mc/s between Monte Peglia (Italy) and Lindau over a distance of 1000 km using a 1,5 kW transmitter and a commercial receiver with a bandwidth of 200 cycles. The antenna gain is 18 db on both ends. Besides the continuous signal level, frequent bursts from meteors and very strong signals from sporadic E have been observed. The back-ground noise shows the transit of the galaxy through the main lobe of the receiving antenna very distinctly. Solar noise has been observed occasionally when the sun was in the main lobe of the receiving antenna. An increase of signal level occurred during some solar flare effects.

13. — Solar eclipse of 30-6-54

Sweep frequency observation were made at Lindau (4), Neuershausen (23) and on board of a french vessel at the Norvegian coast within the zone of totality (18, 29). Sporadic E obscured the E layer during the second half of the eclipse at Lindau and for all the duration at Neuershausen. A drop of the E critical frequency before the first optical contact was observed at Lindau which cannot be fully explained by the screening effect of the sporadic E Layer. The results at the Norvegian coast yielded values of α as low as 1.10^{-7} cm^3 sec^{-1} for the E layer and $3.10^{-8} cm^3 sec^{-1}$ for the F1 layer respectively. The observed form of variation fits best to radiating disk whose diameter is 2 % greater than the optical one.

The current methods of reduction of eclipse data were discussed critically (59). Absorption observations were made at Freiburg on 2,9 and 1,95 Mc/s during the eclipse (58). The different behaviour as observed on these frequencies is explained in terms of the relative contribution of deviative and non-deviative absorption. A separation of these two types was possible.

The variation of the geomagnetic field during an eclipse can be explained by the deformation of the ionospheric S*q* current by a current function Se which is superimposed on the S*q* system and moves with the eclipse (71).

14. — Propagation of very long waves

The theoretical investigations of the propagation of very long waves between a curved earth and a curved ionosphere have been continued and the influence of the magnetic field of the earth has been studied (64, 65, 67). The results were applied to the propagation of atmospherics (66, 68).

15. — Theory of wave propagation

Calculations of the propagation of electromagnetic waves in an inhomogeneous, anisotropic medium were continued. It was shown that in the coupled wave equations the coupling term can be neglected under certain circumstances (62). The propagation of signal groups was investigated using the « method of stationary phase ». Formula for time delay, direction and velocity of group propagation were derived, starting with general expression, and specializing to electromagnetic waves (63).

16. — Solar observations

Solar observations are being continued at the observatories Schauinsland and Wendelstein. A new observatory was opened at Capri in 1955, supplying nearly uninterrupted series of data owing to the great number of cloudless days. A « Map of the Sun » is being issued daily by the Fraunhofer Institut at Freiburg using solar data from cooperating institutions in various countries.

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Italy

N° 161. — Report of the Italian National Committee

The following Italian centres developed ionospheric studies and researches :

(*a*) Istituto Nazionale di Geofisica, Rome

During some periods of time, vertical ionospheric soundings were performed ; recently, the Institute communicated that regular soundings began from January, 1957.

The collaborators of this Institute performed the following studies:

From an examination of vertical soundings data gathered at the ionospheric station of Rome during 1948-1953, the normal behaviour of the ionosphere at Rome has been found : provisional curves predicting the critical frequencies of F2 layer at Rome were calculated (Dominici, 7, 8).

A discussion on the behaviour of the ionosphere at Rome during the partial solar eclipse of June 30, 1954 was given (Dominici, 9).

Dominici (10) performed a general analysis to a first approximation of the effect of a solar eclipse on the ionosphere and applied it to data obtained during some eclipse.

Dominici and Mariani (11) discussed on the most notable aspects of the phenomenology and also the probable formation processes of the F2 region,

Mariani (12) extended the Chapman's theory on photoionization to a non-isothermal atmosphere.

Other studies of Mariani are : a discussion on the effects of the terrestrial curvature on the ionization intensity and on the electron density in a non-isothermal atmosphere (13) ; a study on the ion-electron diffusion in a non-isothermal atmosphere (15) ; a scheme of the temperature distribution in the upper atmosphere with an analysis of the behaviour of the F region based upon this scheme (14).

(*b*) Centro di Studi sulla radiopropagazione e radionavigazione — Napoli

Notes were published about the phenomenon of self-demodulation of radio waves in the ionosphere ; the principal ones have been reported in the referencies (Cutolo 4, 5, 6).

Cutolo, using a wave of 863 kc/s states that as the modulation

frequency increased up 1000 c/s, the received modulation coefficient fell from 0,5 to 0,1, and it remained at 0,1 as the modulation frequency increased to 4000 c/s.

These results are in disagreement with theory, which leads to a factor of demodulation rapidly decreasing with the modulation frequency.

Boella (1, 2) criticized the results of Cutolo, remarking that no sufficient precautions were taken in order to avoid the effects of selective fading, which is usually troublesome at the higher modulation frequencies.

(*c*) Istituto Geofisico dell'Universita di Genova

From 1954 some experiments on ionospheric vertical sounding were performed ; regular vertical soundings are now conducted in the observatory of Monte Capellino (Genova) (Bossolasco, etc , 17, 18).

During I.G.Y., measurements of ionospheric absorption are also planned.

On September 1955, an International Symposium on ionospheric propagation of radio waves was held at Venice, organized by the Italian Society of Physics.

Dominici, Mariani, Cutolo and his collaborators, presented communications about the subjects referred above.

Ranzi discussed some characteristics of F2 region observed in South America : a pre-sunrise shrinkage of F2 region, followed by a rapid expansion, occurring at Buenos Aires two hours before the morning minimum of f_oF2 : a very pronounced midday decrease of f_oF2, observed at Deception Island (63° S, 60°7 W, Antarctics) ; this last phenomenon was attributed by the authors to the vertical drift in the ionosphere, which must be very pronounced in that zone, where a relatively low magnetic dip is associated with the normal increase of the tidal velocity with latitude.

We must mention a note by Caprioli (3), who proposes a calculus procedure in order to determine the collisional frequency of electrons in the ionosphere, assuming that the absorption of a vertical wave is known for all frequencies in a given interval and the ionic density is increasing with height.

A note was published by Ranzi (16) about ionospheric forward scattering of radio waves.

The Italian researches in the ionospheric field are now receiving an important contribution by the « Centro Radioelettrico Sperimentale G. Marconi », by which are in progress from June 1957 observations on back-scatter of ionospheric echoes : the installation comprises a fixed frequency apparatus with a rotating Yagi antenna, and a sweep-frequency sounder with a rhombic antenna directed towards NNE. The program of researches comprises observations on patches of sporadic E and their movements, observations on meteoric echoes, applications of back-scatter soundings to radiocommunication problems, etc.

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Japan

N° 199. — Report of the National Committee to Commission III

by S. Namba,

Chairman, Committee III of the Japanese National Committee

A. — Ionosphere ,Geomagnetism and Radio Wave Propagation

1. — *Theory of the ionosphere*

1.1. *Formation.* — The important role played by electron-ion diffusion under the gravitational field has been emphasized by Yonezawa (1.4, 1.5) in the mechanism of F2 layer formation. By his theory, which took into account the effect of diffusion, the geomagnetic control of the F2 layer can well be explained without considering the electron drift, and the latitudinal distributions of the maximum electron density and its height can be interpreted to some extent. It was shown also by his theoretical study (1.2, 1.3) that the Chapman's distribution of electron density does not change its shape by electron-ion diffusion, and that any arbitrary initial distribution approaches to the Chapman's distribution owing to the diffusion. The theories of formation of the E layer proposed so far were criticized by Inoue (1.6) in the light of recent results of rocket sounding, solar eclipse observation, solar physics research and of experiments of various reactions.

1.2. *Diurnal and seasonal variation and distribution.* — The vertical and horizontal drifts of electrons in the F2 region associated with the geomagnetic variation have been studied by Maeda K. (1.7) and it was shown that the geomagnetic distortion of the F2 layer can well be interpreted as the effect of the drift. According to the investigations by Hirono and Maeda H. (1.8) on the interconnection between the geomagnetic S*q* variation on the magnetic equator and the vertical electron drift in the F2 region it was found that the vertical electron drift can explain the main feature of the F2 region on the magnetic equator. They have also shown that the main term of the drift is diurnal. In connection to the above study, the effects of gravity and ionization pressure gradient were investigated by Hirono (1.9), and it was shown that the effect of the drift is appreciable, unless the number density of atmospheric particles at the height of 300 km is much less than 10^{10} cm^{-3}. By the detailed examination of the daily variations of electron density and height of the F2 layer except on the equator, it was shown by Shimazaki (1.13) (1.14) that their differences with respect to latitudes and seasons can be interpreted as the effect of differences in the amplitude and phase of the semidiurnal variation of electron drift velocity. It was also shown by him (1.15) that the discrepancies in the E layer behaviour from what is expected from Chapman's theory can be attributed to the vertical drift of electrons caused by the S*q* current system.

2. — *Wind system and movements in the ionosphere*

2.1. *Wind system.* — The formulae giving the world-wide distribution and daily variation of the electrical conductivity of the upper atmosphere were deduced by Maeda H. (2.1) (2.2.) from the daily variations of geomagnetism observed at Huancayo from 1922 through 1933 and at 62 stations from 1933. Based on the above result, the dynamo theory as applied to the ionosphere with anisotropic conductivity which varies with the time of day, was mathematically solved by Maeda H. (2.3) and Kato S. (2.5), and then the wind system and static electric field in the E region were calculated. It is worthy noting that the main harmonic term of the wind is diurnal. A similar result as above was obtained by Hirono and Kitamura (2.4), who solved the dynamo equation by means of Integro-Differential-Analyzer and numerical calcu-

lation. The order of magnitude of the wind system obtained by the above studies agrees with the observed one. In these studies the conductivity during night was one of the important factors.

2.2. *Movements.* — The movement of big scale irregularities in the E region has been obtained by Obayashi (2.6, 2.7, 2.8), by studying the fading patterns at MF waves emitted from 3 stations with distances of about 350 to 420 km, during the period from July 1954 through March 1955. Generally speaking, the westward wind with the average velocity of about 80 m/s was predominant around sunset, the wind at winter sunrise was mainly eastward, and during night the wind direction was west-south-westward in spring and autumn, and westward in winter. The extent of the irregularity was estimated to be about 100 to 200 km. Based upon the *h't* records at 2.8 Mc/s simultaneoulsy taken at 3 stations in July and August 1955, the mean drift velocities in the E and F layers were determined to be respectively 50 M/s and 120 M/s by Ogata (2.9, 2.10).

3. — *Ionospheric and geomagnetic disturbances*

*fo*F2 and *h'*F2 observed during the ionospheric F2 disturbances were statistically analyzed into the terms, D_{st} (F2) and S_D(F2) by Sinno (3.1, 3.2). According to his study the followings can be said : S_D(*fo*F2) is predominant in the early stage of magnetic storm, while D_{st} (*fo*F2) develops in a comparatively later stage, and the phase of S_D(*fo*F2) lags in the last stage of disturbance. The average D_{st} (*fo*F2) ever two days after SC is negative in the summer hemisphere and positive in the winter hemisphere, but there exists an abnormal zone around the latitude of 50° in the latter hemisphere, where almost no positive value of D_{st}(*fo*F2) is found. The unusual thing is that D_{st}(*fo*F2) in winter is not always proportional to the geomagnetic activity. The phase of S_D(F2) leads as the solar activity increases.

The ionospheric irregularity associated with the geomagnetic bay disturbance was investigated by Kamiyama (3.3). If the ionospheric current corresponding to the geomagnetic bay disturbance in moderate latitude can be assumed to be caused by the static electric field developed from the current system in auroral zone, the decrease (or increase) of electron density associated

with the rise (or fall) of the height of the F2 layer can be explained by the vertical drift and the positive temperature gradient in the F2 region. It was examined by Sato (3.4, 3.6, 3.7), whether or not the D_{sl}(F2) and D_s(F2) can be deduced from the vertical drift caused by D_s current system, which is assumed to flow in the ionosphere and is estimated from geomagnetic observation. According to his study, good agreements are found between the calculated and observed results near the magnetic equator, but in moderate latitude the agreement is not so good. It was proposed by Nakata (3.8) that the measure of magnitude of S.I.D. is roughly represented by the maximum value of fmin.

4. — *On* F1 ½, Es, E *and* D *layers*

From the statistical study on the materials observed at Tokyo throughout the last solar cycle, it was found by Kasuya (4.1) that the F1 ½ layer appears mostly in the daytime and is prevalent at both equinoxes and there is a good correlation between the frequency of occurrence and the number of sunspots.

A model of the E and D layers was proposed by Kobayashi (4.2, 4.3), which is consistent with the observed results of the absorption of impulse waves at MF and HF, of the variation of *fo*E with change of sun's zenith angle and of the phase height of the E layer at 150 kc/s. And from this model a practical chart for calculating the field intensity of waves reflected from the E and F layers was made by him.

According to the study of Matsushita (4.4, 4.5), it was suggested that a kind of sequential Es, which usually moves downwards and lasts for more than 3 hours, is a downward movement of ionic clouds. He investigated also on the lunar magnetic effect on the equatorial Es.

Based upon the study of the selective fading appearing on the *fcl* traces, some knowledge about the structure of Es was derived by Uyeda and Nakata (4.5). According to their study, there can be two types of Es. The one is of a sharp boundary and appears usually in daytime, accompanying the selective fading on *fcl* trace, and the other has a rough boundary, contains travelling ripples of a scale larger than 3 km and appears mostly during night.

5. — *Outermost ionosphere*

By the ray-theoretical treatment based on Fermat's principle, the formulas necessary for calculating the ray path of a whistler were deduced by Maeda (K) and Kimura (5.1). Their calculations of the ray paths starting from various geomagnetic latitudes, under an appropriate assumption of the electron density distribution in the outer ionosphere, show that the ray path does not in general follow the line of magnetic force and especially in lower latitudes the path is not symmetric with respect to the magnetic equator. Some other observed facts can be interpreted by their theory. Dungey's theory has been extended by Kato (Y) and Akasofu (5.3, 5.9), who investigated the mechanism of geomagnetic micropulsation originating from the magneto-hydrodynamic oscillation in the outer atmosphere. The dispersion relation of the magneto-hydrodynamic waves in the ionosphere was studied by Akasofu (5.8), and it was suggested by him that the downward irregularity observed on *h'-f* ionogram will be due to the shock wave of retarded sound type. According to the study of p. s. c. by Kato (Y) and Watanabe (5.5, 5.7), it is supposed that the origin of p. s .c. is set up outside the ionosphere, and its daily variation is interpreted by the screening effect of the ionosphere. They (5.6) also studied the outer atmospheric oscillation and showed the possibility of occurrence of the giant pulsation.

6. — *Effects of solar eclipse*

A theoretical investigation about the effect of solar eclipse of May 9th, 1948, upon the geomagnetism and the E layer was made by Nagata, Rikitake, Nakata and Yokoyama (6.1). The electron density of the E layer decreased over a wide area and the maximum decrease was about a half of the normal density. The total electrical conductivity was calculated from the observed pattern of the electron density decrease, and by using this the variations of overhead current distribution and of magnetic field upon the earth's surface were theoretically calculated, under the assumption that the solar diurnal variation of geomagnetism is due to the uniform current flowing in the E region. The agreement between the calculated and observed variations of geomagnetism was satisfactory in their shapes as well as in their magnitudes. The geomagnetic measurement with a new

visual magnetic variometer (6.2) was carried out by Kato (Y) and his collaborators (6.3, 6.4, 5.4) in Ceylon, i. e. on nearly geomagnetic equator, in the solar eclipse of June 20 th, 1955.

7. — *Radio wave propagation*

It is well known that radio propagation prediction does not coincide sometimes with the actual propagation condition. A great improvement on this point was attained by Miya and Kanaya (7.1), who took into account the effect of scattering at the ground. The evidence and importance of scattering at the ground were demonstrated by the observation of deviation of arriving direction from the great circle path, which was frequently carried out by Miya and Kanaya (7.2), Arima (7.3), Tabuchi (7.4) and Miya *et al.* (7.5). In these measurements a new visual direction finder with high sensitivity was developed by the last investigators (7.5).

The effectiveness of diversity reception was theoretically studied by Nakagami and Nishio (7.7), and the comparison measurement of impulse and continuous waves at HF was carried out by Inoue *et al.* (7.8, 7.9) in order to investigate the fading mechanism. It was suggested by Uyeda *et al* (7.10) from the measurement of three axis components of the field intensity, that the fading is connected with the curvature of the ionosphere.

The attenuation characteristics at MHF with regards to frequency and distance and the daily variation were obtained by Aono *et al.* (7.11).

In order to improve the reliability of radio disturbance warning by investigating the disturbances of ionospheric propagation, methods of evaluating the received field intensity were examined by Hakura (7.12), the relations between field intensity and 27 day recurrency of solar and geomagnetic activities were studied by Mambo (7.13) and Sinno (7.14).

B. — Solar Surface Phenomena

1. — *Basic materials*

The following phenomena are being observed and published (1.1) quarterly by the Tokyo Astronomical Observatory :

(*a*) Group and total number of sunspots, index of Calcium flocculi and Hydrogen prominence in each quadrant ;

(*b*) Heliographic maps of sunspot, Hydrogen flocculi and dark filament;

(*c*) Times of occurrence, disappearance and maximum, area, central intensity, line width and importance of flare by H spectrohelioscope;

(*d*) Intensity distribution of corona emission around the solar periphery observed at Norikura;

(*e*) Intensity of solar radio waves at 3000, 200, 100 and 67 Mc/s, including abnormal phenomena.

Besides the above publication, the conditions of sunspot, flocculi, prominence and flare is reported monthly (1.2), and a quick information service for sunspot, flare, corona and solar radio wave is made daily by wireless with *U.R.S.I.* or *I.G.Y. Information Code* (1.3).

The materials on sunspot, prominence and flare observed at Ikoma Solar Observatory (1.4) are supplied monthly.

The unusual flare (1.5), which was observed on Feb. 23rd, 1955, accompanied an abnormal increase of cosmic ray intensity.

2. — *On corpuscular stream*

The motion of an ionized cloud in the magnetic field was studied by Kawabata (2.1) and the possibility of escape of a corpuscular stream from the sun was pointed out. Based upon the statistical study it was found by Hatanaka *et al.* (2.2) that (i) geomagnetic K index reaches its maximum in about ten days after the minimum of corona at the east limb for the period of minimum solar activity, (ii) minimum K occurs in about three days after meridian passage of a great sunspot, (iii) maximum K occurs in 5-6 days after meridian passage of a pair group of sunspots, which has magnetic intensity of more than 1000 Gauss and is spaced less than 40°, and (iv) there is no relation between the dark filament and K. Based upon the study of corona it was found by Notuki *et al.* (2.3) that (i) the corona suppresses the intense corpuscular stream from the sun, (ii) the corona can emit locally the weak corpuscular stream, and (iii) the effect of corona is maximum when the active region faces the earth. The 27 day recurrency of geomagnetic disturbance was confirmed by Sinno (2.4) for the period of minimum solar activity, 1950-1953, and it was suggested by him that the maximum of geomagnetic disturbance in vernal and autumnal

equinoxes is related to the intensity distribution of corona. The decrease of cosmic ray intensity was classified by Sekido *et al.* (2.5, 2.6, 2.7) into two kinds, the one associated with geomagnetic storm and the other with no storm. The former kind is related to sunspot group or flare in the vicinity of the group and the latter has no relation to them. Owing to these facts it was suggested that the former storm is caused by the corpuscular stream with magnetism and the latter by the stream without magnetism.

3. — *Solar eclipse*

The expeditions of solar observations (3.1, 3.2, 3.3) in the solar eclipse of June 20th, 1955, were sent to Ceylon from Tokyo Astronomical Observatory (Tokyo University), Astronomical Institutes of Kyoto and Tohoku Universities and to Kukuki Bay of South Vietnam from Hydrological Bureau. The observations in Ceylon were unsuccessful owing to the cloudy weather, but in South Vietnam the observation was carried out successfully.

The observations of solar radio waves at 3000-4000 Mc/s were carried out in three different sites by Tokyo Astronomical Observatory and Research Institute of Atmospherics (3.4, 3.5) and the position and the area of the solar active region were detected and it coincides with the Calcium flocculi.

C. — Night Airglow

Photoelectric observation of the night airglow at 5577 A° has been carried out by Huruhata *et al.* (1) at two different sites in Tokyo and Hokkaido, which are spaced about 1100 km. Based upon these observations, contour maps of airglow were drawn and the height and the movements of airglow and its relationship with *fo*F2 were derived.

Equipments of measuring near infrared OH emissions and of scanning photometry for the I.G.Y. were developed by Ogawa *et al.* (2) and Huruhata *et al.* (3).

D. — Abstracts of the papers submitted to the XIIth General Assembly of U.R.S.I.

A-1. — *Theory of the ionosphere*

1. (n° 32). — A new theory of formation of the F2 layer, by T. Yonezawa (Radio Research Laboratories, Ministry of Postal Services).

The importance is emphasized of the role played by electron-ion diffusion in the mechanism of formation of the E2 layer. Taking into account the

electron-ion diffusion in the gravitational field as well as the electron-ion movement in the vertical direction, the velocity of which is assumed to increase exponentially with height, height distributions of electron density for steady-state conditions have been calculated and discussed. The latitudinal distributions of the maximum electron density and the heigth of its level have also been obtained and compared with observations, resulting in a reasonable agreement at least in their broad features.

2. (nº 23). — Dynamical structure of the ionospheric F2 layer as deduced from its daily variations, by T. SHIMAZAKI (Radio Research Laboratories, Ministry of Postal Services).

Recourse was had to numerical calculations to find the effect of various non-uniform motions due to diffusion, thermal- and tidal-variations on daily variations in the F2 layer. A method of solving the problem was worked out so that the electron density distribution may return back every 24 hours regardless of non-recurrent motions resulted by several causes. The comparison of calculated and observed variations shows that the Bradbury model is better than the Chapman's in every respect. Special emphasis is placed upon the fact that the effect of non-uniform semi-diurnal vertical drift velocities with height gradient of both amplitude and phase is very important.

3. (nº 35). — Difficulties in explaining the formation of the ionosphere, by Y. INOUE (Technical Research Institute, National Defence Agency).

The theories proposed so far on the formation of the E layer are criticized. The arguments of criticism are grounded on rocket-measurement data, variations of the E layer during solar eclipses, results of recent researches in solar physics, and experimental data about rates of various reactions. It is shown that all the formation-theories put forward so far are incomplete. The alternative is needed.

A-3. — *Ionospheric and geomagnetic disturbances*

4. (nº 28). — Ionospheric F2 disturbances associated with geomagnetic storms, by T. SATO (Geophysical Institute, Kyoto University).

The attempt is made to explain the ionospheric F2 disturbances associated with the geomagnetic storms by the electron drift theory. The study is made of the individual states of the disturbances. The results show that the F2 disturbances in the equatorial zone and most of disturbances in middle latitudes can be explained as the effects of the vertical drift of the electron.

5. (nº 26). — Measure of magnitude of sudden ionospheric disturbance, by Y. NAKATA (Radio Research Laboratories, Ministry of Postal Services).

It is described that the magnitude of SID is given by extrapolated maximum value of $f$min shown on the sweep-frequency ft record.

A-4. — *On* F1 1/2, E, E*s* *and* D *layers*

6. (nº 24). — On the occurrence of the F1 1/2, by I. KASUYA (Radio Research Laboratories, Ministry of Postal Services).

From a statistical analysis on a basis of routine ionospheric observations at Tokyo (Kokubunji) throughout the last solar cycle, it is found that the annual, seasonal and diurnal variations exist in the frequency of occurrence of the intermediate layer, the F1 1/2 layer at the middle latitude as Tokyo. The F1 1/2 layer appears mostly in the daytime and is prevalent at both equinoxes, especially remarkable in late spring during years of high solar activity — there has been good correlation between frequency of occurrence and the number of sunspots.

7. (nº 30). — On sequential E*s*, by S. MATSUSHITA (Geophysical Institute, Kyoto University).

One type of E*s* classified as « Sequential », which seems to move generally downward and persists more than three hours, has been investigated, using ionograms obtained at 16 stations.

This type of E*s* appears at about 200 km in winter and about 180 km in summer, and occurs most frequently at 20º-30º N geomagnetic latitude. The time at which sequential E*s* starts to occur and its apparent downward speed depend on the geomagnetic latitude of the station.

The phenomenon of sequential E*s* seems to be a downward motion of a real ionized cloud, or to be a distortion of ionization contours along a slope.

A-5. — *Outermost ionosphere*

8. (nº 34). — Calculation of the propagation path of whistling atmospherics by K. MAEDA, I. KIMURA (Electronic Engineering Institute, Kyoto University).

An approximate method is worked out of calculating the propagation path of a whistler by using Fermat's principle. The paths calculated under some appropriate assumptions of the electron density distribution above the ionosphere show appreciable deviations from the line of magnetic force and are generally asymmetric with respect to the magnetic equator. As to the frequency characteristics of the whistler path, the higher the wave frequency is, the more inside travels the wave.

9. (nº 33). — Magneto-hydrodynamic waves in the ionosphere, by S. AKASOFU (Geophysical Institute, Tohoku University).

The study is made of the magneto-hydrodynamic waves in the ionosphere and the outer atmosphere. The dispersion relations of Alfven waves are obtained and it is shown that various types of geomagnetic micropulsations and ionospheric noises appear in the wide range from audio- to very low-frequency. The Alfvén waves with finite amplitude are also studied. It is suggested that the retarded sound-type shock wave may be identified with the descending « cusps » on hital-*f* curve of ionogram.

A-7. — *Radio wave propagation*

10. (nº 31). — Remarkable lateral deviation in the ionospheric propagation by K. MIYA, M. ISHIKAWA, S. KANAYA (Kokusai Denshin Denwa Co., Ltd.).

Two remarkable lateral deviations in long distance propagation are discussed in detail : One of them is caused by forward scattering on the earth's surface and the other is observed on antipodal waves.

11. (nº 27). — On radio propagation disturbances. by K. SINNO (Hiraiso Radio Wave Observatory, Radio Research Laboratories, Ministry of Postal Services).

In general, it is well known that radio propagation disturbances are excited by geomagnetic storms.

The geomagnetic storms are divided into two groups, the first group having a 27-day recurrence tendency and the second group having no recurrence. It is concluded that the radio propagation disturbances which are caused by the first group are severer then those caused by the second one.

The 27-day recurrent type of magnetic storm has a tendency to often occur at the time when the calm region on the solar surface passes the central meridian of the sun, and the non-recurrent type of the storm corresponds to the solar active region.

It is concluded for the above reasons that the magnetic storms which are related to what is called the « E-region », have a greater effect on radio propagation disturbances.

12. (nº 25). — Some results of a sweep-frequency propagation experiment over a north-south path at a distance of about 1000 km, by Y. AONO and I. KURIKI (Radio Research Laboratories, Ministry of Postal Services).

An oblique-incidence time-delay measurement experiment was conducted sweeping the frequency from 2 Mc through 32 Mc over an 1000 km north-south path, adding the pilot system in pulsed wave of round-trip propagation In comparison with the vertical sounding records of the ionosphere at the midpoint of the path, statistical analysis were made on MUF of F2, E*s* and E layer, discussing the difference frequency of F2 ordinary and extraordinary wave MUF. Brief studies are added further-more on *f*min and nose extension.

13. Wave propagation over irregular terrain, by K. FURUTSU (Radio Research Laboratories, Ministry of Postal Services).

The formula of field strength over irregular terrain is derived on the assumption that the height and electrical property of the earth surface discontinuously change several times along the wave path.

The formula has not any restriction for the magnitude of frequency, and thus may be also applied to diffraction by hills or mountains for all range of frequency.

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2. — *Wind System and Movements in the Ionosphere*

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Nº 227. — Report of Commission IIIc of the National Committee

by I. KOGA, *Official Member*

Since the standard wave transmitted from Japan is not receivable in Europe, special radio time signal is being transmitted from

an overseas radio transmitting station at Oyama about 70 km north of Tokyo, and since June 1956 the signal of seconds has been transmitted regularly for 10 minutes from 12:20, 18:20 and 21:20 UT on Wednesday and Friday every week. The call signs and wave frequencies are as follows :

§ JAG	3	18,570 kc/s
JAG	6	17,597.5
JAO	3	15,945
JAS	32	15,880
§ JAU	4	15,460
JAG	5	12,070
JAO	5	11,012.5
§ JAG	4	10,200
JAO	2	8,175
§ JAQ		7,510

Of these 10 waves the most suitable wave is transmitted according to the season and hour of the day. However, the waves marked by § are most frequently used. Sometimes two waves are transmitted simultaneously.

The signal is operated at the Tokyo Astronomical Observatory at Mitaka at the west end of Tokyo City, and the transmitted radio signal is always monitored at Mitaka.

There are two points about the signal of seconds worthy of report.

(1) The total time taken by the signal to travel from Mitaka to Oyama by land line and from Oyama to Mitaka by air is 25.3 $\pm$ 0.7 milli-seconds. But sometimes it takes about 30 milli-seconds and even 45 milli-seconds, in spite of the fact that the irregularity in the travel time of signal along the land line from Mitaka to Oyama has been ascertained to be within a fraction of milli-second.

After a series of experiments with the help of photographic records of received signals, it was found that such an irregularity of the travel time mentioned above was due to the overlooking of the direct wave when it was very weak compared with a back scattered wave. Thus it is realized that the photographic record is very useful to distinguish the direct wave from the scattered wave or some other abnormal wave.

(2) Both at Hawaii and Tokyo, the standard wave transmitted from the other side is very often receivable. So, from the results

of measurement at both stations, the precise value of travel time of the standard wave can be determined.

Let the instant when the signal was radiated be T_1 and T_2 respectively (see Fig. 1), and the time required for the trans-

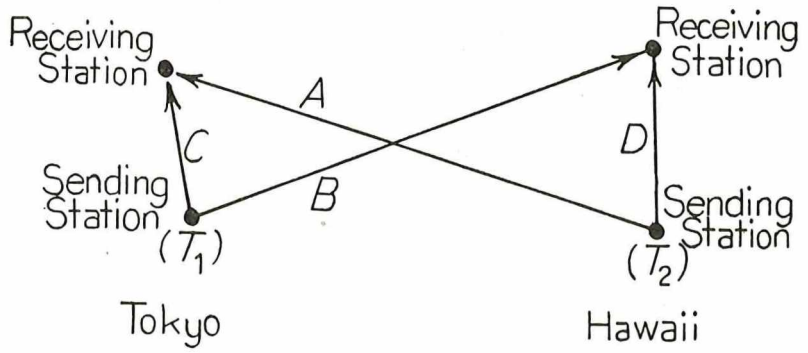


Fig. 1.

mission be A, B, C, D as shown in the figure, then the instant when each wave from Hawaii and Tokyo reaches the receiving station at Tokyo is $T_2 + A$ and $T_1 + C$, respectively. So the time interval (a) between the two signals is :

$$a = (T_2 + A) - (T_1 + C) \tag{1}$$

Similarly the time interval (b) from the two signals at the receiving station in Hawaii is :

$$b = (T_1 + B) - (T_2 + D) \tag{2}$$

From these two relations, we get :

$$a + b = A - C + B - D = (A + B) - (C + D) \tag{3}$$

On the other hand, if we assume that the height of ionosphere is uniform from Tokyo to Hawaii at the same instant, the travel time r of the signal from Tokyo to Hawaii is given by the following equation (see Fig. 2).

$$\tau = 4n\frac{R}{V}\sqrt{\left(1 + \frac{H}{R}\right)\sin^2\frac{\theta}{4n} + \left(\frac{1}{2}\frac{H}{R}\right)^2} \tag{4}$$

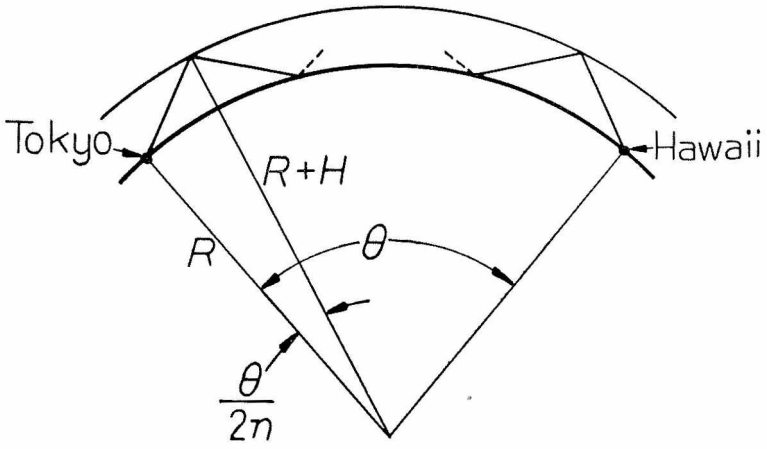


Fig. 2.

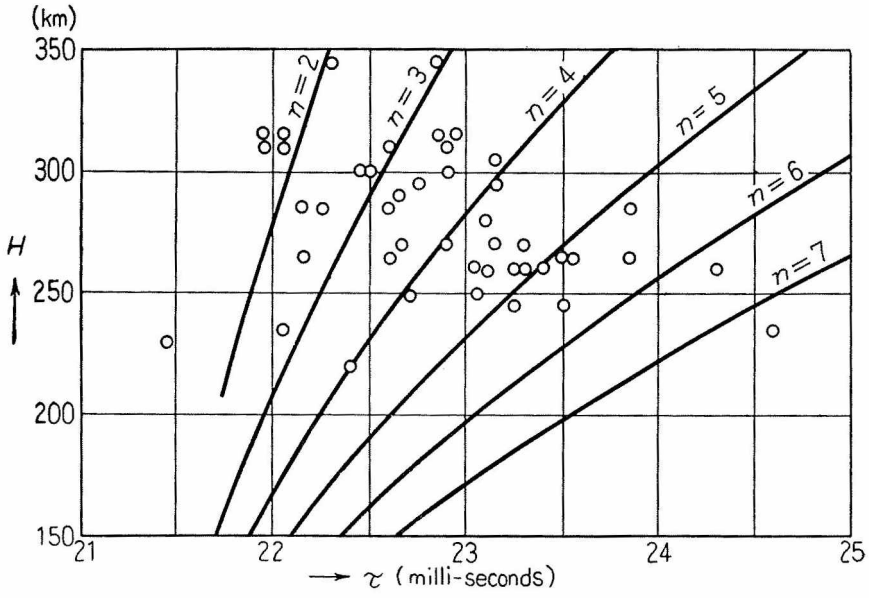


Fig. 3.

where :

n : number of hops,
R : height of the ionosphere,
R : radius of the earth,
V : velocity of radio wave in free space.

In fig. 3 full lines show the relationship between H and τ at various values of n. It was expected that if the height of the ionosphere was determined by a certain method every time when the transmission time τ was measured, all the points plotted in this figure might be nearly on the lines. But the result was rather ambiguous as shown in the figure.

From this fact we realized that the assumption of uniform height between Hawaii and Tokyo was too far away from the ionosphere as it was. Therefore, in order to determine the transmission time it seems necessary that :

(a) we should use the data taken simultaneously at both stations,

(b) remembering that :

$$b - a = 2(T_2 - T_1) \qquad (5)$$

and the regularity of the signal of seconds is reliable enough at present, because at both stations the signal is controlled by a stable crystal clock, it is obvious that b-a must be a constant during a considerable length of time. This fact would be a good check to reject the data of the received signal of irregular character.

(c) After the constancy of b-a has been checked, $\frac{1}{2}(a + b)$ would give the real transmission time of signal at that time. This point will be studied further on, and if any interesting result is obtained, it will be reported at the General Assembly.

Morocco

N° 169. — Report of the National Committee to Commission III

(*Translation*)

Since the XIth General Assembly of U.R.S.I., the political events in Morocco rather impeded the accomplishment of the elaborated programs.

However, if certain studies were delayed or stopped, the ionospheric soundings were made without any severe interruption and it was then possible to safeguard their continuity.

On the other hand possibilities have been found, in the course of 1956, to reconsider the undertaking of the previously outlined programs, and certain of those received a beginning of realization. The International Geophysical Year will then be undertaken, in Morocco, with less material than considered before, but nevertheless with a certain hope in the future.

IONOSPHERE. — In Casablanca, the ionospheric station continued its activity. This station has been equipped to satisfy, at best, the requirements about the accelerated sounding rates asked for I.G.Y. However, from lack of assistance, certain limitations are to be expected.

In Rabat, the Ionospheric Laboratory is progressively improving its equipment.

Field strength recordings of the broadcasting station of Allouis (6200 kc/s) were made from January 1956. This communication is affected by fadings, those observed are reported by Ursigrams and compared with the enhancements of atmospherics on 27 kc/s. These records allowed, at various opportunities, a prefiguration of the I.G.Y.-Alerts in permitting an acceleration of the soundings from indication of a sudden fade-out.

The diurnal variation of the field of this station is the subject of routine recording. It was shown that, on quiet days, the oblique incidence absorption on this frequency, is proportional to $(\cos z)^n$, z being the zenithal distance of the Sun at the center of the paths and n an exponent whose average value, in 1956, is 0,74.

Oblique incidence soundings were operated between Freiburg and Rabat on frequencies about 17 Mc/s in order to monitoring ionospheric predictions. Moreover, differences in lengths in multipath radio-wave propagation were measured and found, for most cases, in agreement with optical propagation.

However, from one and the other side of the nocturnal cut-off period, high and low rays occur. A deeper study of this phenomenon would necessitate a vertical incidence sounding at the vicinity of the center of the path. Some diagrams were drawn in view of this investigation.

The publication of solar maps by Meudon Observatory, of the C.R.P.L. solar data, and of the solar radio noise data from Royal Observatory of Belgium, enabled to establish, from January

1956, a comparison table between solar occurrences and ionospheric anomalies observed in Casablanca. Various interesting features have been revealed from these tables, such as the association of the Es diurnal peaks with flares.

The increase of the nocturnal ionization in the E-region, in the form of a thick layer at about 150 km in height, were associated, with a substantial correlation, with increases in the geomagnetic activity.

Some sudden heightenings of the F region, with a tendency to occur at 05 h and 12 h, were shown to be due to tidal effects, although their causes are not already determined.

The suggestion made in the report of the National Committee of Morocco at the XIth General Assembly, concerning the publication of the anomalies observed at each station in the sounding bulletins, is repeated here.

It does not seem that another method exist for obtaining a synoptic view of the anomalies in the atmosphere, with the purpose of discriminating the local phenomena with those at a larger scale.

The ionization indices of E and F regions were determined monthly by graphical methods. The curves obtained for each region show a rather strong parallelism. For the E-region the exponent n of the formula $fo = fm\ (\cos\ z)^n$ varies erratically around an average value of 0,32, which seems to indicate a positive temperature gradient. For the F-region the exponent n shows a marked seasonal variation, with an average value of 0,22, which indicates a slightly negative temperature gradient; in winter conditions, however, this value raises to 0.25, corresponding to isothermy.

As rocket soundings revealed no negative temperature gradient at the altitude of the F-region, it seems then necessary to investigate other causes than temperature-gradient leading to value of n inferior to 0.25.

Netherlands

N° 167. — Report of the National Committee to Commission III

by J. VELDKAMP

Chairman Committee III of the Netherlands National Committee

REPORT FOR THE PERIOD MAY 1954-MAY 1957

1. — *Vertical incidence ionospheric sounding*

A panoramic recorder with 10 kW output, built by the Geophysical Section of the Royal Netherlands Meteorological Institute was regularly used for routine hourly and half-hourly *h'f* recording at the Ionospheric station De Bilt.

Bulletins (1) of observed data are issued monthly.

The P.T.T. Radio Research Laboratory has built three panoramic recorders with 10 kW output, one for the I.G.Y.-station Paramaribo (Surinam), one for the I.G.Y.-station Hollandia (Netherlands New-Guinea) and one for special investigations at De Bilt (Royal Netherlands Meteorological Institute).

A slow recorder with large output was instituted at the P.T.T. Ionospheric Station Leidschendam.

An experimental set-up was built at Leidschendam for recording ionospheric reflection heights with the aid of decimal counters and a teleprinter. During not too bad signals to noise ratios an accuracy of $\pm$ 0.5 km was achieved.

An electronic coupling of the tuning condenser of an ionosonde with a teleprinter was constructed, enabling the operator to print down critical frequencies during the frequency-sweep. No electronic coupling between the returned echoes and the frequency printer has been constructed up till now.

Experiments were carried out for recording ionograms on magnetic tape instead of photographic film. This seems to be a suitable method for preparing Ursigrams up to the minute.

Investigations are being carried out to produce ionospheric predictions with the aid of an IBM type 650 electronic data processing machine.

2. — *Absorption measurements*

Routine absorption measurements are being made at De Bilt. The technique used for these measurements, the influence of the

ground reflections, short and long period fading, polarization effects and some experimental results have been described (2).

Routine noon values of the absorption index A are published in Monthly Bulletin (1).

3. — *Polarization at vertical incidence*

During more than one year the polarization of vertically reflected radio waves has been observed on 2290 Mc/s and on 3572 Mc/s at the transmitter station Kootwijk by the section I. R. A. of the Netherlands P.T.T.

The elaboration is not yet finished, but probably the results are in accordance with Budden's theory.

4. — *Polarization and long distance radio circuit*

In collaboration with the R.C.A. laboratory the reception at New York was studied of signals that were transmitted circularly as well as linearly polarized from Kootwijk on 18.210 Mc/s. No significant difference was observed.

5. — *Doppler Shifts at vertical incidence*

At Delft Technical University the apparatus for measuring Doppler Shift of a vertically reflected wave with fixed frequency was improved. Measurements will soon be resumed.

6. — *Long wave noise*

Atmospherics are continuously recorded with two loop aerials in the directions NE-SW and NW-SE on 25 kc/s at the P.T.T. receiving station Nederhorst Den Berg (NERA).

7. — *Ionospheric drift*

Regularly ionospheric drift is measured by means of the method of closely spaced receivers on 2290 and 3572 Mc/s at Kootwijk and NERA, simultaneously with drift measurements at Breisach near Strasbourg.

At De Bilt drift measurements are planned, the necessary equipment was constructed.

8. — *Forward scatter*

Two experimental circuits : Kootwijk — South France and Kootwijk — Roma were tested for experimental purpose in connection with the radio service of the Netherlands P.T.T.

The frequency used was 51.3 Mc/s.

9. — *Geo-electric variations*

Geo-electric variations are recorded at Witteveen, at Kootwijk, at Paramaribo and at Hollandia (3).

The relationship between geo-magnetic and geo-electric variations was studied at the magnetic observatory Witteveen of the Royal Netherlands Meteorological Institute (4).

10. — *Miscellaneous*

The Section I.R.A. of the Netherlands P.T.T. investigated some other subjects, viz. : field-strength measurements of W.W.V. and transatlantic circuits, Dellinger effects, ionospheric propagation, round the earth echoes, Ursigram codes.

At De Bilt field-strength records of M.S.F. (England) were regularly made. Some investigations of geo-magnetic solar flare effects were published in *L.A.T.M.E. Bulletin* n° 12*h* (5).

An investigation by the geophysical section of the Royal Netherlands Meteorological Institute on the Equatorial Electrojet, taking into account the obliquity of the earth's dipole axis, was published (6).

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New Zealand

N° 158. — Report of the National Committee to Commission III

1. — CANTERBURY UNIVERSITY COLLEGE PROGRAMME

(a) Radar Observations on Meteors

A considerable programme of work has been carried out at the Springston field station on the radar observation of meteors. A radar survey of the Southern Hemisphere meteors showers has been carried out, and is being repeated using higher sensitivity apparatus to study the incidence of the smaller (high rate) meteors (1, 2 and 3). Work has been done on the radar measurement of meteor velocities, and investigations have been carried out on the factors affecting the detection of meteors by radar methods.

(b) Auroral Observations by Radar

Some of the meteor radar equipment at this station is now being used to study the Aurora Australis, and this work will be continued through I.G.Y.

(c) Ionospheric Studies

A high sensitivity pulsed vertical sounding equipment has been set up, using a frequency of 1.75 Mc/s, for investigations into the ionosphere below the E region. The results of the first six month's work has been published (4) and a further paper is due to be published shortly (5). This work is continuing and a joint

experiment with the Dominion Physical Laboratory is to be carried out on V.H.F. forward scatter, in which the Springston station will be at the mid-point of the V.H.F. path.

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2. — Programme of the Geophysical Observatory (D.S.I.R.)

(*a*) *Vertical Sounding Stations*

The three permanent New Zealand ionosonde stations have all been reequipped for the I.G.Y. and in addition a fourth station has been set up at Scott Base, McMurdo Sound. Raratonga, Godley Head (Christchurch) and Scott Base are all fitted with a new high power (10 kW) panoramic ionosonde with a frequency range of 1-22 Mc/s and a sweep time of 7 seconds. Campbell Island is equipped with a re-built and modified J. 28 outfit. The recordings at these stations will conform with the full I.G.Y. recommendations.

(*b*) *Ionospheric Physics*

A considerable programme of work has been carried out on true heights and electron densities in the ionosphere layers. A method of computing true heights from virtual heights, including the effect of the earth's magnetic field, was developed and was applied to ionospheric conditions at Christchurch.

This was used to compile a picture of a representative day. Further development has been done from this relatively simple picture, particularly with respect to the F region. The results of this work have been published (1, 2, 3, 4, 5).

(*c*) *Ionospheric Storms*

Work has been carried out on the origin and behaviour of geomagnetic sudden commencements and their value as precursors of ionospheric disturbances. This work has been published (6).

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3. — PROGRAMME OF DOMINION PHYSICAL LABORATORY

(*a*) *V.L.F. Propagation*

Observations have been made on the diurnal phase variation of the 16 kc/s transmissions from G.B.R. Rugby, as received in New Zealand, and an explanation has been put forward based on a wave guide mode of propagation for the signals. A paper has been published on the sudden phase anomaly on 16 kc/s transmissions during the solar flare of 23rd February 1956 (1).

(*b*) *Maximum Usable Frequencies*

Over four year's continuous recordings have been made of the times of reception in New Zealand of 15 Mc/s signals from WWVH. The assumption of a multiple-hop mechanism consisting of three ionospheric reflections was found to be more consistent with vertical-incidence data than the usually assumed forward-scattering mechanism implicit in the control-point method of predicting MUFs.

This finding is strengthened by the observation of a large degree of phase coherence in the received signals (2, 3).

(*c*) *Aurora and Airglow*
(*a joint programme with the Carter Observatory*)

During the I.G.Y. the Aurora Australis will be studied by the following means :

(*a*) Observation of MUFs and ionospheric absorption, using pulsed transmissions from McMurdo Sound, Antarctica, with six receiving sites widely scattered on both sides of the Southern Auroral Zone (12-24 Mc/s band).

(*b*) Radar observations from Invercargill (52° S geomag.) on 55 Mc/s.

(*c*) All-sky cameras.

(*d*) Parallax cameras on 180 km base-line, to determine heights of auroral forms.

(*e*) Spectrography (using a U. S. Patrol Spectrograph and U. S. High Dispersion Spectrograph).

(*f*) Visual observations at many locations.

(*d*) *Ionospheric Movements*

Monthly observations using the close-spaced receivers method in the 2 Mc/s band have continued since September 1952. A study has been made of the interpretation of fading records in terms of the interference pattern on the ground. Some alternative methods of determining the velocity of movements have been explored (4, 5, 6, 7). The correspondence between the ground pattern and occurrences in the ionosphere has also been studied (8).

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4. — Programme of Auckland University College and the New Zealand Post Office

Very Long Distance Propagation

Auckland University College at the Seagrove Research Station has been carrying out a series of observations on the bearings and vertical angles of arrival of signals from stations at a great distance, on short waves. They are using a rotating radio interferometer, designed for measuring the slow variations in these angles of arrival, and also a new automatic direction-finder for observations on the rapid fluctuations. Work has been done on the antipodal effect in long distance propagation (1).

The New Zealand Post Office in conjunction with the Seagrove Research Station has carried out a series of observations on special pulse transmissions from Slough (England) and also on transmissions from Osaka in Japan. Observations were made at Seagrove (angles of arrival), Wellington (signal level and pulse shape), and Invercargill (bearings and pulse shape). This work has been published (2).

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Poland

Nº 206. — Report of the National Committee

In the field of ionospheric wave propagation the following topics are considered in Poland.

1. Observations of the possibilities of the reception of short-wave radio signals at long distances in derogation of the MUF (1).

2. Study of the cases of huge concentration of the electro-magnetic wave energy by the ionosphere.
3. Observations of the propagation of the ionospheric waves on the extraorthodromical passes (2).
4. Study on the fadings (3).
5. Study of the methods of the short term ionospheric predictions (4).

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Sweden

N° 215. — Report of the National Committee to Commission III

(Sven GEJER)

VERTICAL INCIDENCE IONOSPHERIC SOUNDING RESEARCH

The three permanent vertical incidence ionosphere stations Kiruna (Research Institute of National Defence), Lulea (Royal Board of Telecommunications) and Uppsala (Research Institute of National Defence) are in continuous operation since several years.

During the International Geophysical Year 1957/1958 a fourth vertical incidence ionosphere station will be in operation at Lycksele (Research Institute of National Defence).

These four Swedish ionosphere stations which will be in operation during the I.G.Y. are in the zone of longitude centred at 10° E

and with a zone width of approximately $\pm 10^{o}$ as suggested in the C.S.A.G.I. resolution, Brussels, 1953.

A ionosphere station at Chalmers Institute of Technology is used for special researches.

In order to fulfil as far as possible the recommendations made by C.S.A.G.I. steps have been taken to improve the installations.

The equipment at Kiruna has been installed in a new building of the Swedish Academy of Sciences and the equipment at Lulea is being substituted by a new one. At Uppsala and Lycksele new ionosonds with a frequency range of 330 kc/s to 22 Mc/s, a power of 50-100 kW and a sweep time of 20 seconds or 3 minutes will be put in operation early in 1957.

Oblique Incidence Ionospheric Sounding Research

Fixed frequency pulse transmitters at Kiruna working on 3 and 8 Mc/s are intended to be recorded in Stockholm from the summer 1957. This research will give more information of the reflection properties of sporadic layers.

Signal Strength Recordings

Continuous recordings of the signal strength from the following stations are made by the Royal Board of Telecommunications at the receiving station at Enköping.

1. The Standard Frequency Station WWV, Washington, on 5, 10, 15 and 20 Mc/s.

The distance is about 6700 km. The path goes through the Auroral Zone.

The reception conditions of WWV during the year 1956 are reproduced in fig. 1. Consideration is not taken to disturbances from other stations. It might be mentioned that the signal strength of the Standard Frequency transmissions from Rugby, MSF, exceeds in general that of WWV on 5 Mc/s. The 15 Mc/s transmissions are disturbed by WWVH and JJY Standard Frequency transmissions during certain hours of the day. There are also disturbances from broadcasting and fixed telegraph stations especially on 10 and 15 Mc/s.

2. London Television Sound Channel, 41,5 Mc/s.

Distance about 1500 km.

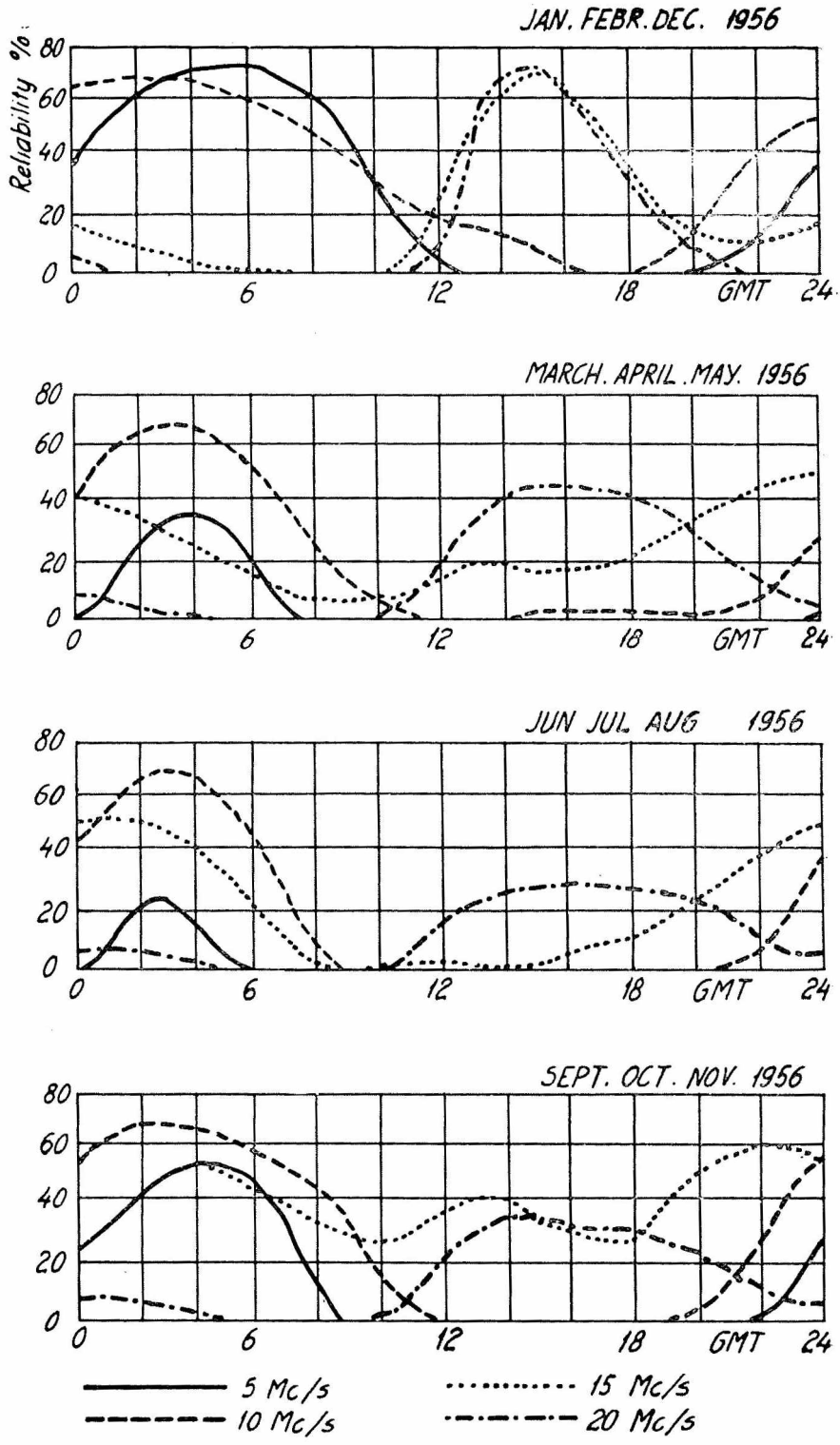


FIG. 1. — Diagrams showing reliability of reception of WWV Standard Frequency transmission as received at Enköping near Stockholm, Sweden. Consideration is not taken to disturbances from other stations.

3. Sutton Coldfield Television Sound Channel, 58.25 Mc/s. Distance about 1500 km.

The recording of the signal strength from the Wrotham FM broadcasting station on 91.4 Mc/s (93.5 Mc/s after 24th January, 1956) ceased in March 1957, the reason being that no signal had been observed since 1953 and during that year only for a few minutes.

The results of the recordings of London, 41.5 Mc/s, and Sutton Coldfield, 58.25 Mc/s, have been dealt with in the following way:

1. The total time during which signal strength at the receiver input has exceeded 5 μV has been summed up for each month.

2. For each month the percentage of distribution of the signal strength for the different hours has been calculated.

In the summer months the received signals are due to sporadic E layer reflexions. For the years 1953-1956 this type of signal reached minimum values during the summers 1954 and 1955, the durations of reception being much greater in the summers of 1953 and 1956. This indicates a dependence of the sunspot number.

During the winter months 1956-1957 the signals have been recorded very often with maximum of reception duration between 1200 and 1600 GMT. Reflexions from ordinary F2 layers are most probably the reason for this propagation.

The Research Institute of National Defence carries out recordings at Kiruna of a low frequency station at a distance of 200 km.

This Institute also makes researches regarding propagation of long waves. The main interest has been concentrated on phase and amplitude recordings of signals from the stations in the Danish Decca Navigation chain which is used for navigation in the eastern part of the North Sea and the south-western part of the Baltic Sea. The four stations transmit on frequencies between about 71 kc/s and 128 kc/s. These investigations will be continued and also extended to cover propagation paths with a reflection point closer to the Auroral Zone.

Researches on Aurora

At the Uppsala ionosphere observatory all-sky aurora cameras have been constructed. Seventeen of these cameras are placed

on stations forming a network in the European sector inside and close to the Auroral Zone and three are operated in the Artic region. A great number of aurora films have been recorded during the past three winters. Synoptic studies of the aurora is made, based on all-sky camera films and visual observations. A theoretical investigation of the reflection of radio waves from distinct aurora forms is made. Further investigations are made of radio reflections during the presence of aurora, especially reflections from sporadic regions in the frequency range 330 kc/s to 22 Mc/s.

Communications during the International Geophysical Year 1957-1958

By the courtesy of the Director General, Swedish Board of Telecommunications, a national centre for communications during the I.G.Y. has been established in Stockholm and telex installations have been put to the free disposal of certain Swedish observatories. The centre is in operation since the beginning of 1957 and hourly values of certain ionospheric data from the Swedish ionosphere stations are sent via telex to the regional centre Paris-Darmstadt-Nera. Also data from the Finnish ionosphere station at Nurmijärvi are retransmitted to the regional centre.

The following work in the field of commission III has been done at the Radio Wave Propagation Observatory of the Research Laboratory of Electronics, Chalmers University of Technology, Gothenburg, Sweden.

Experimental Work

The Kiruna observatory panoramic ionospheric recorder was kept in operation by the Res. Lab. of Electronics until the end of Oct. 1955. The operation of the station was taken over by the Defence Research Laboratories, Jan. 1st, 1956.

The Kiruna observatory auroral radar recorder was kept in operation through April 1955. A new recorder has been built at the Onsala observatory and it will eventually be moved to Kiruna for operation under the next periods of maximum auroral activity.

Irregularities in the polar ionosphere have been studied since 1955 by the observation of the ionospheric scintillations of the Cygnus and Cassiopeia radio sources (at Onsala) on 150 and 33 Mc/s.

A long base line interferometer is under construction for the scintillation measurements.

Theoretical Work

A final report on the results of the 1954 solar eclipse measurements has been completed and is in the process of publication.

A theoretical study of E-layer behaviour during a solar eclipse definitely has shown that eclipse observations (ionospheric) are of little value unless the eclipse is total or almost total.

A preliminary report on the scintillations of the radio sources shows that a quite peculiar effect, the « rate step effect », appears quite regularly. The cause of this effect is not yet known, but it must have some fundamental relation to the formation of the ionospheric irregularities or blobs in the polar and auroral ionosphere.

The problem of the stability of the proposed auroral current ring (extra-terrestrial) has been discussed and surveyed theoretically by N. Wax (Guggenheim Fellow at the Res. Lab. of Electronics 1954-1956).

The reflection of wireless waves from drifting, ionized media, with application to the ionosphere and the solar corona, has been studied theoretically.

A final report of the Kiruna auroral echo observations has been made. The great majority of the echoes observed must be attributed to the aurora.

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Summary. — A series of field intensity recordings in the low-frequency band (70-130 kc/s) have been started in July 1956 over a distance of 600 kilometers. The preliminary results indicate a reflection coefficient less than 0.01 during day-time in summer and varying between 0.4 and 0.7 during summer nights. A sudden change of phase of the sky wave indicating a sudden decrease in height of reflection is observed at a time corresponding to sunrise at the 60 km level. Effects during radio fade outs have been studied indicating an increase in the reflection coefficient (up to 0.16),

The behaviour of simultaneous recordings on two frequencies suggests that the new reflecting layer formed during the fade out appears at a very fixed height independent of time of day and season. The effect of a cosmic storm is mentioned.

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12. N. Wax. — On the ring current hypothesis : *Reports from the Res. Lab. of E.*, nº 41. *Trans. Chalmers Univ. of Techn.*, **171**, 1956.

13. S. Olving, J. Meos. — On the origin of radar echoes associated with auroral activity (In course of publication).

Summary. — An analysis of the auroral echoes at 10 m wavelength, recorded at the Kiruna Radio Wave Propagation Observatory during the first quarter of 1953, indicates that the echoes cannot be disconnected from aurora borealis. It is concluded that the predominant echo mechanism is closely connected to ionized and normally invisible auroral forms. These forms are assumed to be directed along the geomagnetic field lines. It is further very likely that the scattered power received has a strong maximum when the radar wave intersects the ionized auroral geometry perpen-

dicularly, assuming the receiver and transmitter to be situated at the same place. It is not possible to obtain this perpendicularity for a radar at Kiruna except in a very narrow region, if the minimum height, where the scattering takes place, is of the order 90 km. However, the well known sharp maximum of visible auroral activity lies within the E-region, where one normally has a thick auroral ionized layer present (14). Whatever the detailed mechanism of the scattering is, it seems to be important to call attention to the fact that the scattering probably takes place in a medium, i.e. the auroral E-layer, with refractive index somewhat less than unity. This makes the radar ray to bend down slightly, which immediately gives a large area where the condition of perpendicularity can be fulfilled for reasonable low critical frequencies in the layer.

14. O. E. H. Rydbeck, K. Nygard. — Ionospheric observations during the solar eclipse, June 30, 1954 (In course of publication).

15. O. E. H. Rydbeck. — The propagation and reflection of electromagnetic waves in streaming ionized media (In course of publication).

16. T. Orhaug, H. Hvatum. — Observations of radio star scintillations at high latitudes (In course of publication).

Summary. — Observations on radio star scintillations at the Chalmers Radio Wave Propagation Observatory, Gothenburg, on 33 Mc/s and 150 Mc/s have shown a large variation in scintillation rate dependent on sideral time (rate-step). This rate-step has only been observed on 33 Mc/s. A specimen of a scintillation record on 33 Mc/s showing rate-step phenomenon is included.

United Kingdom

N° 124. — Report of the National Committee to Commission III Ionospheric Radio

by W. J. G. Beynon

This report summarises British work carried out in the period June 1954 to March 1957. Further references to certain topics (meteor physics, radio star observations, radio observation of aurorae, etc.) will be found in the report to Commission V.

1. — Vertical Incidence Ionospheric Sounding

(*a*) *Routine h'(f) recording*

Observations have been maintained at Slough, Inverness, Singapore, Ibadan, Port Stanley and Port Lockroy. Observations

at Khartoum were discontinued in 1955 owing to staffing difficulties at the station.

(*b*) *Absorption Measurements*

Routine absorption measurements have continued at Slough, Singapore, Ibadan and Port Stanley and a description of the absorption equipment used at these stations has been published (1). Vertical incidence measurements of ionospheric absorption on a frequency of 2 Mc/s have been analysed in relation to the absorption to be expected for a Chapman-type E layer (2). It has been shown theoretically that when a high frequency wave is reflected from a Chapman layer in the presence of the earth's magnetic field, an important part of the absorption occurs near to the level of reflection (3) and measurements of the absorption made on two frequencies throughout a sunspot cycle support this conclusion (4). A study has been made of the variations to be expected between published measurements of ionospheric absorption at stations a few hundred kilometres apart. After allowing for known sources of error, it is considered that the residual differences observed in summer months are too small to be significant but that real differences probably occur in winter (5).

2. — Ionospheric Forecasting

Prior to 1955, forecasts of maximum usable frequencies were produced in the form of charts based on a division of the world into four zones. In 1955 a new system of presentation was introduced in which contours of critical frequency are plotted on a single World chart for a given hour. Twelve charts for each even hour U. T. are prepared (6).

3. — Analysis of Results from Ionospheric Observations

Methods have been developed for the rapid deduction of electron distribution curves from the observed $h'(f)$ records, taking into consideration the effect of the earth's magnetic field (7). The electron distributions have been determined (neglecting the effect of the field) for a series of magnetically quiet days at different places, seasons and times of day (8) and the resulting information has been used to suggest theories about the processes of electron production and loss in the F1 and F2 layers (9, 10). A study has

been made of the true heights of reflection for layers having parabolic electron density distributions and convenient general expressions derived for the case of contiguous parabolic sections with intermediate layers of various types (11). Some of the perturbations of the F2 layer may be regarded as redistributions of ionization over a range of height and a convenient technique for recognising changes in layer distribution of this kind has been developed (12)

An examination of the maximum electron density in the F2 layer at various magnetic latitudes has shown that the noon equatorial trough previously detected, diminishes towards sunset, and in the late evening is replaced by an equatorial crest (13).

The Chapman theory of ionised layer formation and variation has been modified for quasi-stationary conditions, such as are considered to obtain in the E layer (14). A comparison between actual E layer behaviour and this modified theory has provided direct evidence for the effect of the S*q* horizontal system of currents on the E layer itself (15, 16). The ionosphere, in fact, is found to be a motor as well as a dynamo. Recognition of this result provides reasonable explanations of a number of E layer anomalies previously reported (17). The motor influence of the S*q* current system on E layer characteristics is found to be most simply recognised in terms of diurnal studies of equivalent heights, at high and low latitudes, but the analysis has shown that a west-to-east S*q* current also tends to raise the value of NZ, the peak electron density, while an east-to-west S*q* current tends to reduce it. The result is that NZ is increased in low latitudes, is unaltered at the latitude of the S*q* current focus and is decreased at still higher latitudes. This tendency for NZ to be relatively high in low latitudes is found to explain why the equinox contours of the locations of constant NZ are not circles, with their centre at the sub-solar point, but ellipses with the major axis lying east-west. It also explains why the noon maximum of NZ does not coincide with the sub-solar point at the solstices, but always lies nearer to the equator than that point.

Direct evidence for the influence of the S*q* current system on the peak electron density in the normal E layer has been given, and it has been shown that E layer data can be used to locate the mean positions of the foci of the current systems (18).

4. — Ionospheric irregularities and horizontal movements

Reports summarizing knowledge of irregularities and horizontal movements in the ionosphere have been published (19, 20) and a detailed study made of the application of diffraction theory to waves reflected from an irregular ionosphere (21, 22). A consideration of some detailed points arising in the analysis of fading records from spaced receivers (23, 24, 25, 26) has emphasised the fact that the time delays would be expected to be variable even if the drift velocity were constant. It has been shown that the F region irregularities responsible for the « scintillations » of radio stars are elongated along the direction of the earth's magnetic field, while those responsible for the fading of reflected waves are nearly isometric and show no preferred orientation (27, 28).

It has been shown experimentally that « bursts » of amplitude of high frequency waves reflected from the ionosphere at vertical incidence are caused by focussing effects and the details of the phenomenon have been investigated for the E (29) and F (30) regions. A comparison between ionospheric drifts measured by different methods has shown that the large scale irregularities responsible for focussing, move with the same velocities as the small scale irregularities associated with fading (31). The fading of waves of frequencies between 16 and 2400 kc/s, travelling over different distances, has been studied (32). An equipment for the automatic recording of time-delays between radio fading characteristics has been developed (33).

The effect of ionospheric irregularities on radio direction-finding observations has been studied (34, 35, 36).

5. — The propagation of long and very long waves

Theoretical work on the reflection of long and very long waves from the ionosphere, at vertical and oblique incidence, in the presence of the inclined magnetic field of the earth, has been carried out, partly by analytical (37) and partly by computational (38, 39) methods. It has been shown that a useful theoretical approach to the problem of low frequencies, is to consider the response of the ionosphere to a wave-impulse (40). The variations of the amplitude and phase of the wave reflected at steep incidence, on a frequency of 16 kc/s, has been studied as a function of time of day and of season (41).

6. — Oblique Incidence Ionospheric Propagation

A review of long-distance radio-wave propagation on frequencies above 30 Mc/s has been published (42) and an extensive series of observations made on the propagation of high frequency waves (27, 41 and 89 Mc/s) over distances of 935 and 1.185 km by way of ionospheric forward scattering (43, 44). It has been suggested that such propagation is at least partly maintained by E region bursts of ionization produced by upwardly directed weather-cloud discharges (45) but the suggestion that these discharges give rise to groups of short bursts of signals with a constant time difference has been questioned (46). Other studies of the reception of signals in the band 23-27 Mc/s, over distances of 900 to 1900 km, have also indicated that communication can be sustained for long periods, in both summer and winter, on these frequencies (47).

The ionospheric propagation of high frequency radio waves can be studied by the « back-scatter » technique. Details of equipment developed for such studies have been published (48, 49) and also a description of some of the measurements already made (50). Evidence has been given that for certain propagation paths and ionospheric conditions, back-scattering of signals via region F2 from the ground at points well beyond the transmitter, may seriously interfere with the reception of signals normally received only by forward scattering at region E (51).

A comparison has been made between the performance characteristics of high frequency radio telegraph circuits and those predicted from ionospheric sounding experiments (52). Studies have been made of the arrival angles of pulse signals transmitted over large distances (53). The rapid component of the variation of signal strength from distant radio transmitters operating in the 6 to 18 Mc/s band has been shown to agree closely with a Rayleigh distribution (54). In the experiments described in (54) no significant difference was found between space — and polarization — diversity reception.

Experiments over a distance of 740 km have shown that the fading in the amplitudes of corresponding echoes was reciprocal for 99 % of the time (55), (see also ref. (74)). It is sometimes found that the performance of a trans-equatorial high-frequency radio-communication circuit differs considerably in the two directions. Evidence has been produced which suggests that

this circuit asymmetry may be due to a decrease in the signal/noise ratio in one direction, consequent upon thunderstorm activity in the direction of the main beam of the receiving aerial (56).

7. — Solar Phenomena and the Ionosphere

(*a*) *Ionospheric Observations during Solar Eclipses*

The effects of eclipses on the ionosphere have been reviewed (57) and a number of papers published describing the results of ionospheric observations during solar eclipses in the period 1952-1955 (58, 69). The eclipse of 30th June 1954 occurred at a period of minimum solar activity but ionospheric observations, at both Slough and Inverness, indicated a slight brightening of the solar disc near the extremities of the equator and a slight darkening near the poles, each of these amounting to a departure of about 5 % from uniformity (59, 60). Ionospheric observations during the eclipses of 25th February 1952 and 20th June 1955 have also shown that the distribution of sources of E and F1 layer ionizing radiation is not uniform over the solar disk. Evidence has been given for a probable connection between isolated sources and areas from which 5303A coronal radiation is emitted (61). The analysis of eclipse changes in the F2 layer requires a study of electron density changes at all levels within the layer and also of the influence of movements on the electron density distribution. Papers dealing with the effects observed in region F2 during the eclipses of 1940, 1947, 1952, 1954 and 1955 have been published (62, 63). Radio direction finding measurements, made at vertical and oblique incidence during the solar eclipse of 30th June, 1954, showed that the effective reflecting surface in the F layer was tilted in direction and by an amount of the order to be expected from the geometry of the eclipse (64). Ionospheric absorption measurements on the occasion of the eclipse of 25th February, 1952, indicated a distribution of ionizing radiation over the solar disk in close agreement with that found for the E and F1 layers during the same eclipse (65). Details of eclipse effects observed on 30th June, 1954, in amplitude and phase measurements on long and medium waves at vertical and oblique incidence have been published (66).

The interpretation of ionospheric measurements during solar

eclipses, and in particular estimates of the relative brightness of local sources, depend on the assumed value of the effective recombination coefficient (67). New estimates have been made of effective recombination coefficients for the E and F1 layers, deduced from recent eclipse observations (68, 69).

(*b*) *Index of Solar Activity*

Ionospheric forecasting requires an index of solar activity closely related to the intensity of the ionizing radiation. In the past, the relative Sunspot Number R has been used for this purpose, but ionospheric eclipse measurements have shown that there is no direct connection between sunspots and the sources of the ionizing radiation. Recently a new index of solar activity based on long term critical frequency measurements of region F2 at three widely spaced stations (Slough, Huancayo and Watheroo) has been developed (70). Some of the unusual ionospheric effects observed on the occasion of the great solar flare of 23rd February, 1956, have been described (71, 72) and a survey of recent researches bearing on corpuscular radiation from the sun has been published (73).

8. — Theory

It has been shown that a reciprocity theorem applies to waves incident obliquely in the magnetic meridian on a horizontally stratified ionosphere (74). A method for calculating ray paths through the ionosphere, by means of a digital computor, has been described (75) and has been applied to waves incident on a parabolic distribution of electron density, over a range of frequencies, angles of incidence, and angles of the imposed magnetic field (76). These results have been compared with calculations in which the effect of the magnetic field was omitted, with particular reference to calculations of MUFs. The suggestion that there is a « fourth reflection condition » has been criticised (77).

The influence of the earth's magnetic field on ionospheric turbulence has been considered (78). It has been shown that diffusion probably plays a large part in determining the shape of the F layer, particularly at night (79), and even at the equator, where it can also be responsible for the enhancement of ionospheric irregularities (80). A short survey has been made of the mathematics of wave propagation through the ionosphere (81).

The phenomenon of radio-wave attenuation by way of ionospheric partial reflections and scattering has been examined theoretically, and an equivalence theorem, relating oblique incidence to vertical incidence propagation derived (82).

In theoretical calculations connected with $h'(f)$ observations, values of the « group refractive index » of the ionosphere are required and Tables of this parameter have been computed (83).

For other theoretical papers see references (3, 7, 14, 21, 22, 28 and 37 to 40).

9. — Miscellaneous

A method has been developed, using a special kind of frequency change modulation for detecting weak ionospheric echoes reflected from the D region on a frequency of 1.4 Mc/s (84, 85).

Absorption measurements at night have been used to estimate the variation of the critical frequency of the normal E layer at such times (86).

A study of sporadic E measurements over a period of years suggests the existence of a subsidiary stratum of ionisation of low reflection coefficient which is almost always present (87).

A method has been described for the calibration of an ionospheric recorder which corrects errors in height measurement arising from distortion of the echo pulse during transit through the receiver (88).

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U. S. A.

N° 297. — Report of U. S. A. Commission III of U.R.S.I. Progress in ionospheric research in the United States between the XIth and XIIth Assemblies

Ionospheric research in the United States has been reported to technical meetings sponsored by the U. S. A. National Committee of U.R.S.I., by 29 laboratories. In the bulk of this report, the titles of papers so presented are listed under the institution from which the work came. Brief descriptions of the fields of research undertaken, together with bibliographies of published papers, are presented as well for some of the most active laboratories.

A. — A. D. Ring and Associates

III. — *U.R.S.I. papers*

1. « A study of the relative merits of horizontally and vertically polarized skywave signals near the gyromagnetic frequency ». C. S. Wright, May 1957, Washington D. C.

B. — Air Force Cambridge Research Center

I. — *Activities*

The Ionospheric Physics Laboratory of the Geophysical Research Directorate :

Prior to the shipment of a high dispersion spectograph to New Zealand for auroral studies during I.G.Y., attempts were being made to obtain higher resolution in the infrared region of the night sky spectra at middle and low latitudes. When the new improved *f*0.8 spectrograph now being constructed is completed, new observations will be made to determine rotational temperature given by highly resolved OH bands in the IR.

Development of a high aperture sequence camera designed to take photographs at fraction of a second exposures has been completed and will be utilized when the autumnal equinoxial increase in aurora commences.

Development of a photometer to measure the height distribution of Hβ in the aurora. This instrument is presently being used at one of the Antarctic stations during I.G.Y.

Design and construction of equipment has been completed for the study of the mechanisms of auroral scatter across the auroral zone. This equipment is to be installed in the Alaskan area.

A very considerable amount of effort and time during the past two years has been spent in planning the I.G.Y. Auroral Program, particularly that phase involving the auroral patrol spectrograph. This patrol spectrograph has been based on a joint study by this laboratory and the University of Chicago. This laboratory also has the responsibility for the entire Antarctic and Arctic Auroral Program.

The installation of an airborne ionospheric recorder has been supplemented by devices able to record the amplitude of the ionospheric reflections. A magnetometer, also, has been installed for the purpose of monitoring the geomagnetic total field strength. The results of several arctic flights show how the mobility of the airborne equipment can be used to track large scale irregularities and reveal some part of their important role in arctic radio communication (5,9).

A new method of measuring ionospheric drifts has been developed using the airborne equipment while the aircraft is flying on a circle.

The effects of airtides on the ionosphere has been the subject of theoretical and experimental investigations. The dynamo currents in the ionosphere have been computed using spherical harmonics and the concept of balance of power. The results compare favorably with the Bartels Sq current system and show an amplification factor of 100 for the wind at the level of the ionosphere (7).

Experimental data from ionospheric records taken at stations around the equator and with the airborne equipment confirm the theoretical concept and illustrate some of the details (3, 14).

Rocket experiments have been carried out to determine the electron density from pulse delay data. An exact method for analysis was developed for use with high speed electronic computers. Results on the E layer show a pronounced stratification or lamination of the layer consisting of a number of horizontal strata about 6 km apart in height, each stratum being made up of irregular patches of ionization (2, 13, 10, 11).

II. — *Published papers*

1. « Studies of the Refractive Index in the Ionosphere : The Effect of the Collision Frequency and of Ions », W. PFISTER, *Report on the Conference on the Physics of the Ionosphere*, Cambridge 1954, published by the Physical Society, 1955.
2. « Further Remarks on Bifurcation in the E-layer », W. PFISTER, J. C. ULWICK, R. J. MARCOU, *Phys. Rev.*, **97**, 1183, 1955.
3. « The Effect of Tides and Electric Currents in the Upper Atmosphere on the Ionospheric Characteristics in Equatorial Regions », G. J. GASSMANN, U.R.S.I. meeting, May, 1955, Washington, D. C.
4. « Diurnal Rotation in the Ionosphere », K. TOMAN, *U.R.S.I.*, Gainsville, Fla., Dec., 1955.
5. « Airborne Ionospheric Measurements in the North Pole Area », G. J. GASSMANN, *U.R.S.I. Meeting*, Oct. 1955. Gainsville, Fla.
6. « Ionospheric Effects on the Positioning of Vehicles at High Altitudes », W. PFISTER, T. J. KENESHEA, *Air Force Survey in Geophysics*, nº 83, March, 1956.
7. « The Dynamo Currents in the Ionosphere Obtained with Spherical Harmonic Analysis and the Principle of Balance of Power », W. PFISTER, T. J. KENESHEA, *U.R.S.I. Meeting*, May, 1956, Washington, D. C.
8. « A Patrol Spectrograph for the I.G.Y. », N. J. OLIVER, Optical Soc. of America, Pittsburg, June, 1956.
9. « Measurements of Irregularities and Drifts in the Arctic Ionosphere using Airborne Tecniques », G. J. GASSMANN, *Proceedings of the Symposium on Polar Atmosphere*, Oslo, Norway, July, 1956.
10. « On the Distribution of Electron Density Determined by Rocket Experiments », W. PFISTER, *Symposium on Wave Propagation*, Sept., 1956, Paris, France.
11. « The Results of Some Rocket Experiments for Electron Density Distribution », J. C. ULWICK, *U.R.S.I. Meeting*, Oct. 1956, Berkeley, California.
12. « An « Unusual » Solar Terrestrial Relationship », K. TOMAN, *U.R.S.I. Meeting*, Oct. 1956, Berkeley, California.
13. « Study of Fine Structure and Irregularities of the Ionosphere with Rockets and Satellites », W. PFISTER, published in *Scientific Uses of Earth's Satellites*, edited by J. A. VAN ALLEN, pp. 283-291, University of Michigan Press, Ann Arbor, 1956.
14. « Measurements and Interpretation of Tidal Effects in the Equatorial Ionosphere », G. J. GASSMANN, *U.R.S.I. Meeting*, May 1957, Washington, D. C.
15. « A Further Analysis of Solar Terr. Correlation », K. TOMAN, *U.R.S.I. Meeting*, May 1957, Washington D. C.

III. — *U.R.S.I. papers*

1. « Airborne ionospheric Measurements in the Northpole Area », G. J. Gassmann, Gainsville, Fla., Dec. 1955.
2. « On the Analysis of Electron Density Distributions From Rocket Data », James C. Ulwick, Gainsville, Fla., Dec. 1955.
3. « On the Origin of Nocturnal E Ionization », M. Dubin, Washington D. C., April 1956.
4. « The Dynamo Currents in the Ionosphere Obtained with Spherical Harmonic Analysis and With the Principle of Balance of Power », W. Pfister, T. J. Keneshea, Washington D. C., April 1956.
5. « An Unusual Solar-terrestrial Relationship », Kurt Toman, Berkeley, California, Oct. 1956.
6. « The Results of Some Rocket Experiments for Electron Density Distribution », James C. Ulwick, Berkeley, Cal., Oct. 1956.
7. « Measurements with Voice Transmissions by Ionospheric Scatter on 38.6 Mc », I. R. M. Wundt, Berkeley, California, Oct. 1956.
8. « Measurement and Interpretation of Tidal Effects in the Equatorial Ionosphere », G. J. Gassmann, Washington, D. C., May 1957.
9. « Ionospheric Reflection of Very Low Frequencies », H. Poeverlein, Washington, D. C., May 1957.

C. — Carnegie Institution of Washington

III. — *U.R.S.I. papers*

1. « On the process Causing the Dependence of Size of Crochets (terrestrial magnetic effects of Solar flares) upon the Amplitude of the Magnetic Diurnal Variation », Scott E. Forbush, Gainsville, Fla., Dec. 1955.

D. — Collins Radio Company

III. — *U.R.S.I. papers*

1. « Flight Measurements of Transmission Loss at 38,5 Mc », I. H. Gerks, Washington, D. C., May 1957.

E. — Cornell University

I. — *Activities*

Work at Cornell University has been concerned with the scattering of radio waves in the ionosphere produced by irregularities of electron density.

A guiding principle in this work has been the assumption that

the irregularities are due to atmospheric turbulence and that the principles of fluid mechanics that have been developed to describe turbulence in other situations are also applicable in the ionosphere. In practice, it has been assumed that the turbulence is isotropic since fluid mechanics is better developed for this stituation than for non-isotropic turbulence. It is not, however, known to what extent turbulence in the ionosphere is non-isotropic. What we have done, therefore, is to use the theory of isotropic turbulence with a view to explaining the following phenomena :

1. Ordinary fading of ionospheric echoes ;
2. The phenomenon of spread F ;
3. Backscattering from field-aligned ionization in the F region ;
4. Scintillation of radio stars ;
5. Irregularly fading echoes from long duration meteor trails ;
6. Back scattering below the E region at 2 megacycles per second ;
7. Long distance scatter transmission in the VHF band ;
8. Backscattering in the VHF band from regions of auroral activity.

II. — *Published papers*

1. « A Theory of Scattering by Non-isotropic Irregularities with Application to Radar Reflection from the Aurora », H. G. Booker, *Journal of Atmospheric and Terrestrial Physics*, 1956, Vol. 8, pp. 204-221.
2. « Turbulence in the Ionosphere with Application to Meteor Trails, Radio Star Scintillation, Auroral Radar Echoes and other Phenomena », H. G. Booker, *Journal of Geophysical Research*, Vol. 61, Dec. 1956, p. 673.
3. « A Theory of Long Duration Meteor Echoes Based on Atmospheric Turbulence with Experimental Confirmation », H. G. Booker, Robert Cohen, *Journal of Geophysical Research*, Vol. 61, Dec. 1956, p. 707.
4. « A Theory of Radio Stars Scintillation Based on Ionospheric Turbulence », H. G. Booker, Spring *U.R.S.I. Meeting*, May 1957.

III. — *U.R.S.I. papers*

1. « Auroral Echoes Observed North of the Auroral Zone on 51.9 Mc/s », R. B. Dyce, Washington D. C., May 1955.
2. « Echoes at 106.5 Mc/s Associated With Thunderstorms », B. Nichols, G. C. Rumi, Gainsville, Fla., Dec. 1955.
3. « A Theory of Scattering by Non-isotropic Irregularities with Application to Radar Reflections from the Aurora », H. G. Booker, Gainsville, Fla., Dec. 1955.

4. « Some Comments on the Specular Meteoric Theory of Ionospheric Scatter-transmission », H. G. Booker, Washington D. C., April 1956.
5. « A Theory of Long-duration Meteor-echoes Based on Atmospheric Turbulence », H. G. Booker, Washington, D. C., April 1956.
6. « An experimental Study of Atmospheric Turbulence in the Lower E-region Using Meteor Echoes of Long Duration », R. Cohen, Washington, D. C., April 1956.
7. « H. F. Radar Echoes with Unusual Characteristics », G. C. Rumi, Washington, D. C., April 1956.
8. « A Theory of Radio Star Scintillation Based on Ionospheric Turbulence » H. G. Booker, Washington, D. C., May 1957.

F. — Dartmouth College — Thayer School of Engineering

High-frequency studies

The vertical incidence polarization studies described in the Commission's report to the XIth General Assembly (Document 121, U.R.S.I. XIth Assembly, The Hague, 1954) were continued through 1955 December. The results of this experiment are essentially the same as those outlined in 1954.

Between 1954 May and 1955 August, a series of fixed-frequency oblique-path pulse experiments was made, the first of these taking place between Hanover, N. H. and Washington, D. C. and the remaining ones between Hanover and Knob Lake, Quebec. The vertical-incidence transmitters at Hanover were used, one feeding a horizontal half-wave dipole and the other a vertical monopole, to provide a controlled-polarization signal. Polarization of the signals received at the remote points was not measured.

It was found that one of the received components in a multipath transmission could usually be eliminated by controlling the transmitted polarization, However, the geometry of the path was not established and hence the polarization of the transmitted wave was not known, even though the phasing and relative amplitudes of the signals fed to the transmitter antennas were determined.

An LG-17 (Canadian Marconi Company) ionosphere recorder was placed in operation in 1955 in the summer. A sweep-frequency, oblique-path experiment, in which the LG-17 was to be synchronized as to timing and frequency with a similar unit operated at Saskatoon, Saskatchewan was commenced in January 1956 but was discontinued shortly.

Instrumentation is now being developed for the operation of the sounder with two synchronized receivers placed 100 km away in orthogonal directions from the sounder. Three ionograms will be produced from the single sweep-frequency transmitter. This will permit determination of the height and the velocity vector of moving reflecting patches. The experiment will first be operated at Hanover and then at Knob Lake which is in the auroral zone.

Whistlers and VLF emissions

In 1955 March, simultaneous records of whistlers were made at Hanover, N. H. and Washington, D. C. in collaboration with the Naval Research Laboratory (H. E. Dinger). It was found that the dispersion of a given whistler heard at both places is the same.

The theory of whistlers was completed by L. R. O. Storey in his graduate studies at Cambridge University in 1951 and it was reported to the Xth Assembly by his professor, J. A. Ratcliffe. In order to validate the Storey theory conclusively on the basis of predicted time delays and dispersions in whistler echo trains as received at geomagnetically conjugate points on the earth, simultaneous recordings were made at Unalaska, Alaska and Wellington, New Zealand in 1955 during August and September. The observations in New Zealand were made by the New Zealand Dominion Physical Laboratory (G. McK. Allcock). Spectrographic analysis of the recordings revealed complete agreement with Storey's postulates.

It is not uncommon to have a single lightning flash produce two or more separate whistlers having different dispersions. Usually the multiple whistlers are closely spaced in arrival time. Because the spacing within successive groups is constant during a given period of activity, it is concluded that this is certainly due to the existence of separate propagation paths.

In a record obtained at Unalaska, 1956 Nov. 11, it was found that the first two whistlers were unusually widely-spaced multiples, and that the succeeding echoes could be explained by successive propagation over these two paths in various sequential combinations. One of the original pair was stronger than the other. Assuming that this path therefore had the smaller attenuation,

one would expect to find preference exhibited for it in the echoes, and this was found to be the case.

After many failures, a completely successful observation was made at Hanover, N. H. correlating the visual perception of lightning with the aural perception of whistlers. Flashes were occurring three or four minutes apart and each produced a strong whistler with echoes. There were no other significant sferics audible and no other whistlers.

Observations have been made in the Arctic near the W75 meridian in 1956 and 1957 in July. No whistlers have been heard above N65 geomagnetic but VLF emissions (dawn chorus) have been heard up to N90 geomagnetic.

With the knowledge that VLF emissions and aurora are both strongly correlated with geomagnetic disturbance, it is reasonable to seek a direct correspondence between VLF emissions and visible features of the aurora. This has now been found and is under further study. The correlation is with the bright patches which course rapidly up auroral rays.

At the suggestion of J. M. Watts of the National Bureau of Standards, the « tweeks » on the routine three-hourly recordings made at Hanover before and after the great solar flare of 1956 Feb. 23 have been analyzed. The result substantiates the findings of others that the level of reflection of VLF signals in the dark hemisphere dropped to 70 km.

A multi-channel audio-frequency spectrum analyzer for the rapid analysis of data has been developed. Records are produced on continuously moving 35 mm photographic film on which the image of a row of thirty-two small cathode ray tubes is focused.

I.G.Y.-Whistlers

A meridional chain of 13 stations to observe the latitude dependence of whistlers and vlf emissions has been set up approximately along W75. The stations are located at :

Thule, Greenland,
Godhavn, Greenland (cooperating Danish station),
Frobisher Bay, NWT, Canada,
Knob Lake, Que., Canada,
Father Point, Que., Canada (or a site nearby),

Hanover, N. H.
Washington, D. C.
Bermuda,
Gainsville, Fla.
Huancayo, Peru,
Ushuaia, Tierra del Fuego, Argentina,
Port Lockroy, Antarctica (U. K. station on Palmer Peninsula),
Ellsworth, Antarctica (U. S. station on Weddell Sea).

In addition, a station has been set up at Battle Creek, Mich. The Canadian Defence Research Board is operating stations at Ottawa and Halifax which are coordinated with these stations. All but two of these stations are in routine operation or nearly so.

Special apparatus was developed for the I.G.Y. whistler stations. It includes a local time standard good to $\pm 1/20$ second which places time marks directly on the tape with the records. Two minute recordings are made hourly, commencing precisely at 35 minutes past the hour.

To provide guidance and insure standardization for all countries observing these phenomena during I.G.Y., a manual was prepared for the U.R.S.I.-A.G.I. Committee. This has been incorporated in the C.S.A.G.I. Manual for ionospheric physics (Annals of I.G.Y., vol. 3).

An agreement has recently been reached insuring that all participants in the coordinated Western Hemisphere program will use a uniform reporting sheet for the daily log of aural monitoring of tapes. This program includes eleven stations in addition to those mentioned foregoing. The other stations are in the Western part of North America and the conjugate area in the South Pacific.

I.G.Y.-Other

All-sky cameras and visually recording magnetometers are being installed at Hanover, N. H. and Knob Lake, Que.

Papers presented

1955 March (National Academy of Sciences, Washington). — M. G. MORGAN, « Planning the U. S. I.G.Y. Program in Ionospheric Physics ».

1955 May (U.R.S.I. Spring Meetings, Washington). — Symposium on audio atmospherics, Joint Commission 3-4 Meeting ; M. G. MORGAN discussed

« records obtained at Dartmouth College and their correlation with records from Knob Lake, Que., Washington, D. C., and Gainsville, Fla.

1955 Dec. (U.R.S.I. Fall Meetings, Gainsville, Fla.). — M. G. MORGAN, G. McK. ALLCOCK, « Observation of whistlers at geomagnetically conjugate points ».

1955 Dec. (Amer. Asso. for the Advancement of Science, Atlanta, Ga.). — M. G. MORGAN, « The Ionosphere ».

1956 April (U.R.S.I. Spring Meetings, Washington). — M. G. MORGAN, H. W. CURTIS, « On the dependence of whistler dispersion upon the geomagnetic latitude of the generating sferic ».

1956 Oct. (U.R.S.I. Fall Meetings, Berkeley, Calif.). — H. W. CURTIS, M. G. MORGAN, « Whistlers and dawn chorus occurrence above the auroral zone ».

1957 Jan. (VLF Symposium, C.R.P.L. Boulder, Colo.). — M. G. MORGAN, H. W. CURTIS, « Whistlers and dawn chorus at Unalaska and their correlation with simultaneous data at the geomagnetic conjugate ; Whistlers and dawn chorus at Knob Lake, Que ».

1957 June (National Academy of Sciences, Washington). — M. G. MORGAN, « U. S. I.G.Y. Program in ionospheric physics, Current status » ; M. G. MORGAN, « Whistlers studies at Darthmouth College ».

Publications

M. G. MORGAN, W. C. JOHNSON. — « The observed polarization of high-frequency sky-wave signals at vertical incidence », *Report of* (the Physical Society), 1954 *Cambridge Conference*, p. 74.

M. G. MORGAN — « Comment on « Instantaneous Frequency », *Proc. I.R.E.*, 1954 Nov., p. 1698 (Correspondence).

M. G. MORGAN, H. E. DINGER ; M. G. MORGAN, G. McK. ALLCOCK. — Observations of whistling atmospherics at geomagnetically conjugate points », *Nature*, 1956 Jan. 7, pp. 29-31.

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M. G. MORGAN. — « Correlation of whistlers and lightning flashes by direct aural and visual observation », submitted to *Nature*, 1957 June.

DARTMOUTH COLLEGE — PHYSICS DEPARTMENT

I.G.Y.

Automatic ionospheric absorption apparatus is being set up at Hanover and Knob Lake, Que. using the galactic noise technique.

Publication

C. G. LITTLE, W. M. RAYTON, R. B. ROOF. — « Review of ionospheric effects at VHF and UHF », *Proc. I.R.E.*, 1956 Aug., p. 992.

G. — HARVARD UNIVERSITY

I. — *Activities*

Meteors by radio and optical methods.

III. — *U.R.S.I. papers*

1. « Diurnal Rotation in the Ionosphere », K. TOMAN, Gainsville, Florida, Dec. 1955.

I. — HUGHES AIRCRAFT COMPANY

III. — *U.R.S.I. papers*

1. « Interference Measurement of Small Multipath Delay Changes », DE FOREST, L., TRAUTMAN, Jr., Washington, D. C., April 1956.

J. — LINCOLN LABORATORY, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

I. — *Activities*

Research related to scatter propagation at frequencies above the MUF, VHF reflection theories for meteoric echoes, and VHF studies of the aurora.

III. — *U.R.S.I. papers*

1. « Scatter Heights Determined from VHF Pulse Measurements », W. G. ABEL, Gainsville, Fla., Dec. 1955.
2. « Long Distance High Power Radio Propagation at Frequencies Exceeding the MUF », W. G. ABEL, M. L. PHILLIPS, Washington D. C., April 1956.
3. « On meteor echoes from Under-dense Trails at Very High Frequencies », Morton LOEWENTHAL, Berkeley, California, Oct. 1956.
4. « Measurements in an Aircraft of 50 Mc Field Strength Along a 1500-mile Path », William G. ABEL, Berkeley, Oct. 1956.
5. « On the Reception of HF Waves above the Classical MUF », Martin BASLER, Washington, D. C., May 1957.

6. « Forward Scattering by Reflections from Meteor Trails of a UHF Signal over an 830 Mile Path », James H. Chisholm, Morton Loewenthal, Alfred E. Teachmann, Washington, D. C., May 1957.
7. « UHF Auroral Observations », S. J. Fricker, R. P. Ingalls, M. L. Stone, S. C. Wang, Lincoln Lab., Washington, May 1957.
8. « Variations of E-layer Scatter Receptions with FE*s* », M. Lindeman Phillips, Washington, D. C., May 1957.

K. — Navy Electronics Laboratory (San Diego)

I. — *Activities*

1. *VLF and LF Propagation.* — Very low Frequency and Low Frequency Propagation Research at the U. S. Navy Electronics Laboratory has been concerned primarily with a study of amplitude variations of transmitted signals. During 1954 and 1955 NEL conducted a program of air-borne measurement of VLF field intensities out to about 7000 km from various U. S. Navy transmitters. The data was compared with empirical VLF field intensity formulas and J. A. Pierce's formula was found to give the most accurate prediction.

A plot of signal amplitude as a function of distance indicated an interference pattern out to 4000 km for daytime propagation and out to 7000 km, the maximum distance at which observations were obtained, for night-time propagation. The interference pattern was analyzed using a ray model of propagation. From this analysis information concerning ionospheric reflection coefficients, height of ionospheric reflection, and phase change on reflection of the wave front at the ionosphere was obtained.

Work concerning Low Frequency Propagation includes the analysis of a 135.6 kc/s signal recorded at sites about 1500 km from the transmitter in the Alaskan area. From the analysis, the « R » component of the ionospheric reflection was obtained for an oblique angle of incidence. The night-to-night variation throughout the night-time period was obtained. A several-week mean of the daytime reflection coefficient was obtained.

2. *Carrier-phase Variation of a 40 kc/s Signal on the San Diego-Seattle Path.* — During 1955, an 8-day experiment recorded the apparent phase-delay variations of a 40 kc/s radio signal on the San Diego-Seattle path. Alternately transmitting at intervals

in the order of one second, Seattle transmission was phase-locked to received San Diego transmissions. A San Diego monitor observed the phase variations of the Seattle signal as compared to radiated San Diego signal phase. Diurnal phase change of approximately 50 microseconds (round trip) was observed increased delay occurring during night-time. Maximum range of scatter of short-time phase variations about the long-time mean occurred during night-time and was approximately 10 microseconds « round-trip » value.

3. *Study of Radio Transmission at HF on a 200 mile Over-Sea-Water Path.* — During 1956 tests were conducted using sub-carrier frequency division multiplexing of several radio-teletype signals on a 200 mile over-sea-water path. Carrier frequencies in the 2 to 3 Mc/s region were found to provide better 24 hour teletype-communication than frequencies of from 6 to 12 Mc/s. This was apparently the result of decreased multi-hop interference and decreased co-channel interference from the smaller geographic area from which ionospheric transmission of interference may occur.

Using dual frequency diversity to combat multipath fading, it was found that as little as 170 cps frequency separation of sub-carriers was effective in reducing error rate from this cause.

4. *Forward scattering of Radio Waves from Meteor Trails.* — Since the summer of 1955 the Stanford University Radio Propagation Laboratory has operated at Palo Alto, California, a 43.5 Mc/s radio transmitter with output power of a few hundred watts broadly directed toward San Diego by a 3 element Yagi antenna. At the San Diego terminal of the 690 km path, the Navy Electronics Laboratory has monitored the R.P.L. transmissions, using a similar 3 element Yagi antenna connected to conventional receiving and recording equipment.

Signal spikes observed to erupt intermittently above the noise level are interpreted as being produced by forward scattering of the transmitted radiation by ionized trails of meteors. Analysis of the records reveals the following :

(1) Rates of occurrence of signal spikes are several times as high in early morning (0600) as in late afternoon (1800) as might be expected from the kinematics of the earth's motion in a field of sporadic meteors.

(2) Intervals between signal spikes have a Poisson distribution as expected from statistical considerations.

(3) Distribution of durations of exponentially decaying signals spikes at l/e times peak amplitudes shows a maximum at a duration of about 0.2 sec. The durations show a diurnal variation, being longer in the afternoon than in the morning.

(4) Distribution of amplitudes indicates that the number of echoes N having amplitude greater than A is given approximately by $N = 1/A^m$. For the decay type echoes (underdense trails) $m = 1$, and for the persistent type echoes (overdense trails) $m = 4$ approximately.

II. — *Published papers*

1. J. Bickel, J. Heritage, S. Weisbrod. — « An Experimental Measurement of VLF Field Strength as a Function of Distance Using an Aircraft », *N.E.L. Report*, 767, Feb. 1957.

2. J. Bickel. — « A Method of Obtaining LF Oblique Incidence Reflection Coefficients and its Applications to 135,6 kc/s Data in the Alaskan Area », To be published in Sept. 1957 issue of *Journal of Geophysical Research.*

3. H. J. Wirth. — « Preliminary Observations of Forward Scattering of Electromagnetic Waves Meteor Trails », *N.E.L. Report* 690, May, 1956.

4. T. J. Keary, H. J. Wirth. — « Observations of Forward Scattering of 43.5 Mc/s Radio Waves from Meteor Trails Over a 690-km Path from Palo Alto, California, to San Diego, California », presented at *U.R.S.I. Meeting*, Berkeley, California, Oct. 1956.

III. — *U.R.S.I. papers*

1. « A study of Recent VLF Oblique Incidence Propagation Data », J. L. Heritage, S. Weisbrod, Washington, D. C., May 1955.

2. « Study of LF Propagation Path Characteristics in the Alaskan Area », John E. Bickel, Washington, D. C., May 1955.

3. « Some Features of VLF Propagation Deduced from Aircraft Flight Data », J. L. Heritage, S. Weisbrod, J. E. Bickel, Washington, D. C., April 1956.

4. « Observations of Forward Scattering of 43.5 Mc/s Radio Waves From Meteor Trails over a 690-km Path from Palo Alto, California, to San Diego, California », T. J. Keary, H. J. Wirth, Berkeley, Oct. 1956.

L. — National Bureau of Standards

I. — *Activities, Radio Propagation Physics Division*

A substantial effort, particularly during the past year and one half, has gone into preparations for the I.G.Y., including preparation of manuals for ionospheric vertical soundings, ionospheric, scatter, and aurora and airglow. A new ionosphere recorder NBS Model C-4, was designed and put into production. Four units were sent to the Antarctic Continent. Personnel were trained for and sent to five ionosphere stations in Antarctica, including the South Pole station. Preparations were made for additional ionosphere stations in South America, a world data center to contain airglow and ionospheric physics data for the western hemisphere, the organization necessary for issuing « alerts » and specifying « special world intervals » by the I.G.Y. World Warning Agency, an equatorial ionospheric forward scatter experiment, an experiment to measure sporadic E reflection coefficients at oblique incidence in various parts of the world, and a western hemisphere chain of airglow photometers.

Beginning in November 1955, solar-geophysical data formerly included in the C.R.P.L.-F series « Ionospheric Data », were published separately as C.R.P.L.-F Part B entitled « Solar Geophysical Data ». The scope was expanded and now includes regular reports of daily solar indices (relative sunspot numbers and 2800 Mc/s solar flux), solar centers of activity (calcium plage and sunspot regions, and coronal line emission indices), solar flares (optical observations, and ionospheric effects), solar radio noise observations, geomagnetic activity indices, and radio propagation quality indices.

Work on the relationship between ionospheric disturbances and solar phenomena included statistical studies of the relationship of geomagnetic disturbances to the occurrence of Hα filaments and to the configurations of magnetic maps of the sun.

Theoretical studies of aerodynamical mechanisms producing electronic density fluctuations showed that on certain reasonable assumptions regarding the distribution of electron density and turbulence in the E region several of the characteristics of sporadic E can be accounted for. A comprehensive theory of the oscillations of the earth's atmosphere was developed which took account of

input of thermal energy at all heights and frictional losses. Applications to the dynamo theory of the diurnal geomagnetic variations were made.

Oblique path sweep frequency studies were continued with experiments over a 2370 km path. In a great majority of cases the oblique *p'-f* records were obscured in the vicinity of the « nose » (where the high ray and low ray coalesce) by scattering. A relatively thin trace of a scatter echo sometimes extended as far as two megacycles beyond the normal « nose » MUF. In cases where the « nose » MUF could be distinguished through the clutter, it was found to be higher (about 5 %) than the MUF obtained by applying a standard transmission curve to the *h'-f* record obtained simultaneously at the midpoint of the oblique path. Values of the MUF obtained from sweep-frequency backscatter records scaled at the range corresponding to a skip distance of 2370 km along the same path agreed with the « nose » MUF to within about 1 %.

The characteristics of the ionosphere at low frequencies, including polarization, were studied using a pulse sounder sweeping in frequency from 50 kc/s to 1100 kc/s. An improved sounder, with a loop antenna having an area of approximately 111,000 square meters, was recently installed near Boulder, Colorado.

Studies of the arctic ionosphere included analysis of the temporal and geographical distribution of ionospheric sounding blackouts, a determination of the latitude distribution of auroral zone absorption using oblique path field strength measurements across the auroral zone, and observation of relationships between aurora and sporadic-E echoes.

A comprehensive analysis of the world-wide occurrence of sporadic E was carried out based primarily on vertical incidence data (*f*E*s* and *h'*E*s*) but including all available information.

Investigations of VHF ionospheric (« forward ») scatter were continued with emphasis on special experiments to elucidate the physical mechanisms involved, the fading characteristics, the heights at which the scattering takes place, polarization changes, and dependence upon frequency and scattering angle. Two survey articles were published. Pulse delay experiments at 50 Mc/s over an 810 km path showed that scatter took place predominantly between 85 and 90 km during night time, and between 70 and 85 km (given erroneously as 60 to 75 km by Pineo,

1956) during daytime. Later tests with sharply beamed antennas showed that the most favourable path for the scatter is deviated slightly from the great circle path during roughly two thirds of each day. It was concluded that overlapping meteor echoes play the dominant role during the night time hours, while turbulent scatter is dominant only during the six to eight hour period centered on noon. Routine recording over half of one complete sunspot cycle suggests that the scattered power varies with long-term sunspot activity. Successful transmissions over a 2270 km path proved that practical communications can be achieved over circuits up to about that length when elevated antennas are used. An experiment with individual bursts of signal from meteor trains using sharply beamed antennas agreed well with the published prediction of Eshleman and Manning that the most probable echoing region varies with time of day. The results agree with an ecliptic concentration of meteor orbits.

Study of the radio noise emitted by the planet Jupiter at 18 and 20 Mc/s showed that Jupiter possesses an ionosphere with a critical frequency of roughly 15 Mc/s which appears to change with the solar sunspot cycle in much the same way as the ionosphere of the earth. Statistical analysis of the occurrence of the noise yielded a precisely determined period of rotation indicating that the noises originate from a rigid core beneath the clouds.

Observational work on the night airglow started at Fritz Peak near Boulder, Colo., in January 1955, with the installation of a photometer transferred from the Cactus Peak station in California. In October, 1956, a second photometer was installed which includes a birefringent filter for the elimination of background radiation from astronomical sources. The large accumulation of data is being measured with the help of an oscillogram reader which puts the measurements on punched cards. Particular emphasis is being placed on the synoptic study of the data including a number of nights when simultaneous observations were made at Fritz Peak and at Sacramento Peak, 500 miles to the South. In preparation for the I.G.Y., an observing station is being established at Rapid City, South Dakota, which will be operated under NBS supervision. Equipment made at Boulder has been installed at Camden, Australia, and a cooperative research program is in progress.

II. — *Published papers*

1. « Some results of sweep-frequency investigation in the low frequency band », J. M. WATTS, J. N. BROWN. *J. Geophys. Research*, **59**, 71-86, March 1954.
2. « A note on sweep-frequency backscatter observations », R. SILBERSTEIN. *J. Geophys. Research*, **59**, 138-9, March 1954.
3. « Motion of the Storm-D regions », V. L. AGY. *Nature*, **173**, 445-448, March 6, 1954.
4. « Sweep frequency backscatter — some observations and deductions », R. SILBERSTEIN. *Trans. I.R.E., P.G.A.P.*, 2, 56-63, April 1954.
5. « Procedure used to improve the quality of ionospheric data », S. C. GLADDEN. *Trans. Am. Geophys. Union*, **35**, 398-404, June 1954.
6. « Location of the auroral absorption zone », V. L. AGY, *J. Geophys. Research*, **59**, 267-272, June 1954.
7. « A technique for sweep frequency polarization measurements at low frequencies », E. L. KILPATRICK. *J. Geophys. Research*, **59**, 345-349, Sept. 1954.
8. « On the paper « Maximum usable frequencies and lowest usable frequencies for the path Washington to Resolute Bay », S. M. OSTROW, *J. Geophys. Research*, **59**, 434, Sept. 1954.
9. « Predictions of the present sunspot cycle », A. G. MCNISH, J. V. LINCOLN, *Trans. Am. Geophys. Union*, **35**, 709-710, Oct. 1954.
10. « Geographic and temporal distribution of polar blackouts », V. L. AGY, *J. Geophs. Research*, **59**, 499-512, Dec. 1954.
11. « Observations of distant meteor-trail echoes followed by ground scatter» W. L. HARTSFIELD, *J. Geophys. Research*, **60**, 53-56, March 1955.
12. « A review of observational results in airglow photometry », F. E. ROACH, *Ann. Geophys.*, **11**, 214-230, April-June 1955.
13. « Scattering at oblique incidence from ionospheric irregularities ; summary of an informal talk », D. K. BAILEY, Phys. Soc. London ; Physics of the Ionosphere, Report of Sept. 1954, Cambridge Conference, 1955, pp. 99-100.
14. « Radio transmission at VHF by scattering and other processes in the lower ionosphere », D. K. BAILEY, R. BATEMAN, R. C. KIRBY. *Proc. I.R.E.*, **43**, 1181-1231, Oct. 1955.
15. « Aerodynamical mechanisms producing electronic density fluctuations in turbulent ionized layers », R. M. GALLET, *Proc. I.R.E.*, **43**, 1240-1252, Oct. 1955.
16. « Some fadig characteristics of regular VHF ionospheric propagation », G. R. SUGAR, *Proc. I.R.E.*, **43**, 1432-1436, Oct. 1955.
17. « Solar H_a filaments and geomagnetic disturbances », H. I. LEIGHTON, D. E. BILLINGS, *J. Atm. and Terrest. Phys.*, **7**, 349-350, Dec. 1955.

18. « Some results of a sweep-frequency propagation experiment over an 1150 km east-west path », B. WIEDER, *J. Geophys. Research*, **50**, 394-409, Dec. 1955.

19. « Sweep-frequency pulse-transmission measurement over a 2400-km path », P. G. SULZER, *J. Geophys. Research*, **60**, 411-420, Dec. 1955.

20. « Thermal and gravitational excitation of atmospheric oscillations », H. K. SEN, M. L. WHITE, *J. Geophys. Research*, **60**, 483-495, Dec. 1955.

21. « Extension of the Sen-White paper on atmospheric oscillations », M. L. WHITE, *J. Geophys. Research*, **60**, 531-532, Dec. 1955.

22. « VHF Propagation by ionospheric scattering a survey of experimental results », R. C. KIRBY, *Trans. I.R.E.*, CS-**4**, 17-27, March 1956.

23. « Relationships between aurora and sporadic-E echoes at Barow, Alaska », R. W. KNECHT, *J. Geophys. Research*, **61**, 59-69, March 1956.

24. « Ionospheric effects produced by solar flare radiation ». V. AGY, *Phys. Rev.*, **103**, 917, May 1956.

25. « Oblique incidence measurements of the heights at which ionospheric scattering of VHF radio waves occurs », V. C. PINEO, *J. Geophys. Res.*, **61**, 165, 1956.

26. « Gravitational and thermal oscillations in the earth's upper atmosphere» M. L. WHITE, *J. Geophys. Res.*, **61**, 489, 1956.

27. « A study of magnetic maps of the sun », M. B. WOOD, *Ap. J.*, **124**, 447, 1956.

28. « The absolute photometry of the Gegenschein », F. E. ROACH, M. H. REES, The Airglow and the Aurorae, Pergamon Press, London, 1956.

29. « The wold-wide occurrence of sporadic-E », E. K. SMITH, NBS Circular 582, March 1957.

30. « An observation of audio frequency electromagnetic noise during a period of solar disturbance », J. M. WATTS, *Journ. of Geophys. Res.*, **62**, 199, 1957.

31. « On the atmospheric dynamo theory », M. L. WHITE, *J. Geophys. Res.*, **62**, 329, 1957.

32. « I.G.Y. instruction manual for ionospheric vertical soundings », J. W. WRIGHT, R. W. KNECHT, K. DAVIES, *Annals of the I.G.Y.*, Vol. III, Part I, 1957.

33. « The NBS equatorial regional VHF scatter research program for the I.G.Y. », K. L. BOWLES, R. COHEN, Q.S.T., Aug. 1957.

34. « NBS work on Jupiter's radio emissions are discussed by R. M. GALLET in Cahp. 14, of « Planets and Comets », Vol. 3 of The Solar System.

35. « I.G.Y. instruction manual for miscellaneous radio measurements », Section on ionospheric scatter by K. L. BOWLES.

36. « I.G.Y. Instruction manual for aurora and airglow : Chapter 5, photometric observations of the airglow » by F. E. ROACH.

37. « Arc-lengths along the lines of force of a magnetic dipole », S. CHAPMAN, M. SUGIURA, *J. Geophs. Res.*, **61**, 485, 1956.

38. « A comparison of the annual mean solar and lunar atmospheric tides in barometric pressure, as regards their worldwide distribution of amplitude and phase », S. CHAPMAN, *J. Atmos. and Terr. Phys.*, 8, 1956.

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40. « I.G.Y. instruction manual for aurora and airglow », S. CHAPMAN, *Annals of the I.G.Y.*, Vol. IV, 1957.

41. « The solar and lunar daily variations of horizontal geomagnetic force at Greenwich », S. CHAPMAN, 1957.

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44. « Survey of geomagnetic eclipse phenomena », S. CHAPMAN, in *Solar eclipses and the ionosphere*, Pergamon Press, London, 1956.

45. « Notes on the solar corona and the terrestrial atmosphere », S. CHAPMAN, Smithsonian Contributions to Astrophysics, Vol. 2, nº 1, 1957.

III. — *U.R.S.I. papers*

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2. « Sweep frequency pulse measurements of ionospheric propagation over a 2400 km path », V. AGY, P. G. SULZER, Washington, D. C., May 1955.

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9. « Measurements of the F2 layer deviative absorption variations by cosmic noise method », R. M. GALLET, Gainsville, Fla., Dec. 1955.
10. « An empirical transmission curve for an 1150 km e-w path », B. WIEDER, Gainsville, Fla., Dec. 1955.
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12. « Sid-type phenomena and solar flares », J. V. LINCOLN, Gainsville, Fla., Dec. 1955.
13. « A statistical study of sudden ionosphere disturbances », Vaughn AGY, Gainsville, Fla., Dec. 1955.
14. « Gravitational and thermal oscillations in the earth's upper atmosphere », Marvin L. WHITE, Gainsville, Fla., Dec. 1955.
15. « Oblique incidence radio observations of meteor trails », G. R. SUGAR, Washington D. C., April 1956.
16. « Ionospheric motions observed on high-frequency backscatter soundings », L. H. TVETEN, Washington, D. C., April 1956.
17. « A fading origin experiment for radio waves reflected from the ionosphere », T. N. GAUTIER, R. S. LAWRENCE, W. F. UTLAUT, B. WIEDER, Washington, D. C., May 1957.
18. « Ionospheric effects of the great solar-cosmic ray event of February 23, 1956 », A. H. SHAPLEY, R. W. KNECHT, Washington D. C., May 1957,
19. « Some VHF sporadic-E results », R. M. DAVIS, Jr., J. W. FINNEY. E. K. SMITH, Jr., D. H. ZACHARISEN, Washington D. C., May 1957.
20. « A long distance pulse propagation experiment on 20.1 Mc/s », Richard SILBERSTEIN, Washington D. C., May 1957.
21. « Numerical computations from the theory of VLF noise emissions and their comparison with observations », R. M. GALLET, Anne HESSING, Washington, D. C., May 1957.
22. « A systematic classification of natural VLF noises other than whistlers », R. M. GALLET, D. L. JONES, Washington, D. C., May 1957.

M. — NEW-YORK UNIVERSITY

I. — *Activities*

1. *Radio Scattering.* — As is well known, radio waves of appropriate frequency can be scattered by turbulence-induced refractive index fluctuations, which occur in different regions of the atmosphere ranging from the lower troposphere to the upper ionosphere. The model currently favored to explain this « dielectric noise » is the mixing action of atmospheric turbulence acting

in regions of refractive index inhomogeneity, especially in gradients of refractivity. According to this model the regions of the atmosphere (in particular the ionosphere) which can support scatter propagation are those which have asufficiently high level both of turbulent activity and of refractive index inhomogeneity. Other things being equal, this favors regions of the ionosphere where the electron density gradient is the steepest, a fact which appears to be supported by experiment.

The research at New-York University in radio scattering theory has been largely concerned with the turbulent mixing theory and its consequences for radio scattering. One report « On Radio Scattering by Dielectric Turbulence » by R. A. Silverman, EM-98, September, 1956, deals with the formulation of the radio scattering problem in its appropriate mathematical language, namely the theory of random processes. The relation between the dielectric noise responsible for radio scattering, which is a random function of space and time, and the received scattered radiation, itself a random function of time and antenna siting, is developed in detail. Although its tone is somewhat more rigorous than the prevailing literature, the physical circumstances of actual scattering experiments are not lost sight of.

Another of our reports « Turbulent Mixing Theory Applied to Radio Scattering », by R. A. Silverman, EM-88, January 1956, concerns the application of the Kolmogorov-Obukhov turbulent mixing theory to radio scattering. In this paper the failure of certain heuristic mixing theories to adequately take into account the complicated inner structure of turbulent mixing is analyzed, and experimental evidence is adduced in favor of the statistical mixing theory of Kolmogorov-Obukhov. This evidence is drawn from both meteorological and radio observations. The model supported by this paper, which is also the model preferred by Prof. G. K. Batchelor of Cambridge has been opposed in two recent papers by Dr. A. D. Wheelon of the Ramo-Wooldridge Corporation, but has received further confirmation, both experimental and theoretical, at the hands of Mr. Ralph Bolgiano, a research student at Cornell University. In our view, the competitors to the Kolomogorov-Obukhov theory contain evident defects, although the applicability of the Kolomogoroff-Obukhoff theory to radio scattering experiments, especially those at the lower frequencies, is still very much an open issue.

In the most recent of our reports on radio scattering « Fading of Radio Waves Scattered by Dielectric Turbulence » by R. A. Silverman, EM-101, January, 1957, the time structure of fading characteristics of electromagnetic radiation scattered by dielectric turbulence is examined. In this paper the fading of the received radiation is interpreted as the result of two effects, first, the convection of the scattering eddies by the macro-eddies and by the mean wind, and second, the change in the scattering eddies as seen in a coordinate system which moves along with them. (It should be noted that the problem of separating these two effects is a very difficult problem in turbulence theory and that much further work remains to be done). The conclusion reached in this paper is that it may be possible to detect an observable departure of the fading rate of scattered radiation as a function of frequency from the linear Doppler law that would be caused by the convective effect alone. It need not be added that this conclusion is perforce rather speculative, knowledge of the time structure of dielectric turbulence being as uncertain as it is.

Certain subsidiary studies made by our group should be mentioned. First of all, recent work in the foundations of turbulence theory made by Dr. R. Kraichnana and summarized in two recent reports « Relation of Fourth to Second Moments in Stationary Homogeneous Hydromagnetic Turbulence », MH-6 and « Statistical Mechanics in Stationary Homogeneous Hydromagnetic Turbulence», MH-7 give promise of leading to some results concerning the structure of turbulently mixed scalar fields, such as those we are concerned with in radio scattering. Secondly, the radio scattering problem has led to the consideration of certain mathematical problems, of considerable interest in their own right. We have in mind, the theory of locally stationary random processes described in our report MME-2 by R. A. Silverman, April 1957, and some as yet unpublished work by the same author on the fading rate of the envelope of Gaussian noise.

2. *The Inverse Propagation Problem.* — The direct and natural method of calculating the effect of the troposphere or the ionosphere on radio wave propagation is of course to obtain the index of refraction of the entire medium through which the waves may pass and then to tackle the mathematical problem of solving Maxwell's equation in that medium and with a given source.

In the case of the ionosphere the impossibility, at least until the recent use of rockets, of obtaining experimental information on the index of that medium has forced the adoption of alternative procedures such as deriving the ionospheric index on the basis of reasonable physical assumptions (the Appleton-Hartree formula) or the use of time delay information. As a consequence of research in the theory of differential equations it seems possible to improve on existing methods of determining the ionospheric index. Our method presupposes a knowledge of the phase of the reflected wave at various frequencies at normal incidence. For non-dispersive media we could alternatively use the reflection coefficient at single frequency and various angles of incidence. At the present time method is limited to isotropic media.

We utilize the theory of the differential equation :

$$u''(k, x) + k^2 n^2(x) u(k, x) = 0$$

wherein we have shown that if the asymptotic form of the solution at $x = -oo$ is known, then under various conditions previously described it is possible to determine $n(x)$. This asymptotic form is $e^{ikx} + b(k)e^{-ikx}$ and physically $b(k)$ is the reflection coefficient for the wave e^{ikx} of unit amplitude incident from $-oo$. The $n(x)$ of the above equation determines the index of refraction of the medium. Hence a knowledge of the reflection coefficient as a function of frequency determines the index. The precise conditions on $b(k)$ and on $n(x)$ which enable one to determine $n(x)$ from a knowledge of $b(k)$ are given. It is also shown how one can obtain $n(x)$ explicitly for a large class of reflection coefficients. This theory is contained in our report, « The Inverse Scattering Problem», EM-74, by I. Kay.

If one neglects collisions and the Earth's magnetic field, the electron density of the ionosphere can be calculated from the time of travel of a pulse sent up to the ionosphere and reflected by it, provided this time is known as a function of frequency from zero to some frequency and, what is more important, provided the electron density increases monotonically with height. In the case of multiple layers (those with more than one maximum) the method yields less. We have considered the question : Suppose we had more information than soundings from the ground, how could we utilize them ? Continuing to treat propagation

in the ionosphere from the group velocity point of view, we could postulate that we have a station above the ionosphere, and that we can make soundings from below, above, and through the ionosphere. The last type of information, the time of transit of a pulse through a valley (a region between maximum ion densities) as a function of frequency (from penetration frequency to infinity), permits us to calculate the width of the valley at any given electron density. For more complicated electron density distributions we can obtain the cumulative width of the valleys. Since the mathematical procedure involves taking a Mellin transform and later an inverse Mellin transform it is applicable, for the time being, to transit times which are analytic functions of frequency ; a suitable approximation procedure would have to be worked out to handle numerical data. Because the above method uses the group velocity only, we cannot obtain the ion distribution uniquely, but the procedure is simpler and yields such information as the depths of valleys, curvature at the bottom, and other quantities. The theory is contained in our report « Calculation of Charge Density Distribution of Multilayers from Transit Time Data », EM-82, by S. Karp and J. Shmoys.

3. *The Measurement of Virtual Height.* — A new definition of the virtual height of a reflected wave train is recommended. This definition is such that its accuracy increases as the width of the incident pulse increases. Moreover it is theoretically possible to obtain an estimate of the virtual height with as small an error as desired no matter what the nature of the reflecting medium. Suppose an incident pulse having width W and a carrier frequency ω_0 produces a reflected wave which, when measured at a fixed point $x = 0$ in space, is $R(\omega_0, W, t)$. The suggested definition of the virtual height $h'(\omega_0)$ is :

$$h'(\omega_o) = c \lim_{W \to 00} \frac{\int_{-\infty}^{+\infty} t \left| R(\omega_o, W, t) \right|^2 dt}{\int_{-\infty}^{+\infty} \left| R(\omega_o, W, t) \right|^2 dt}$$

where c is the free space velocity of light. This relation for $h'(\omega_0)$ holds for any physically reasonable incident wave train and is independent of its envelope shape. This work is yet to be written up by Dr. I. Kay.

II. — *Published papers*

1. Silverman, R. A. — « Turbulent Mixing Theory Applied to Radio Scattering », *Jour. Appl. Phys.*, 27, 1956, p. 699.
2. Silverman, R. A. — « Fading of Radio Waves Scattered by Dielectric Turbulence ». *Jour. Appl. Phys.*, 28, 1957, p. 506.
3. Silverman, R. A. — « Locally Stationary Random Processes ». *Trans. I.R.E., Professional Group on Information Theory* (in press).
4. Moses, H., Kay, I. — « The Determination of the Scattering Potential from the Spectral Measure Function », 11 *Nuovo Cimento*, 2, 1955, 917.
5. Karp, S., Shmoys, J. — « Calculation of Charge Density Distribution of Multilayers from Transit Time Data », *Jour. of Geophys. Res.*, 61, 1956, p. 183.

III. — *U.R.S.I. papers*

1. « Low Frequency Long range Propagation Problem », J. Shmoys, Washington D. C., May 1955.
2. « On the measurement of Virtual Height », I. Kay, Washington D. C., May 1957.

N. — Pennsylvania State University

I. — *Activities*

The work of this Laboratory is concerned with the following factors :

1. *Low Frequency Vertical Incidence Measurements.* — Several years of data have been obtained involving the following measurements on 75 kc/s. Equivalent height versus time, change in phase path versus time, ionospheric absorption and sky wave polarization.

2. *Mathematical Studies.* — Various methods of solving the complete wave equations have been devised from the viewpoint of obtaining electron density height profiles in the lower E and D regions. The methods include simple graphical procedures as well as schemes utilizing a rather large scale digital computer.

3. *Ionospheric Physics.* — Studies have been completed and others are underway concerned with the physical and chemical constitution of the lower ionosphere involved in region formation in terms of the possible solar radiations effective in producing the various lower ionospheric regions.

4. *Ionospheric Properties.* — Experimental and/or theoretical work related to certain ionospheric properties have been completed or are now underway as follows : Instrumentation is essentially completed for the procurement of long wave *h'-f* records over the range 50 kc/s to 800 kc/s. Initial measurements on 75 kc/s of phase path fluctuations utilizing three spaced receivers and their interpretation in terms of ionospheric characteristics are now underway. Short wave vertical incidence ionospheric absorption measurements are being procured for the I.G.Y. An analysis of certain I.G.Y. *h'-f* data is being made for the I.G.Y. utilizing a digital computer to convert such data to electron density height profiles with primary emphasis on the determination of temporal variations in these profiles. A rather extensive theoretical and experimental study is being made of long wave sun rise effects and the night time E-layer. An experimental program utilizing amplitude fluctuations at three spaced receivers on 75 kc/s is underway in a study of drifts, etc. in the lower ionosphere.

5. *Rocket Measurements.* — An experimental program is being initiated to determine electron density versus height profiles in the D and lower E regions of the ionosphere utilizing rocket borne equipment.

IIa. — *Published papers*

1. « The Determination of the Electron Density Distribution of an Ionosphere Layer in the Presence of an External Magnetic Field », J. M. Kelso. *J.A.T.P.*, Vol. 5, 11-27, March 1954.
2. « A Tentative Model of the Equilibrium Height Distribution of Nitric Oxide in the High Atmosphere and the Resulting D-Layer », A. P. Mitra, *M.A.T P* , Vol. 5, 28-43, March 1954.
3. « The Dissociation of Oxygen in the High Atmosphere », M. Nicolet, P. Mange. Published in *J.G.R.*, Vol. 59, 15-45, March 1954.
4. « The Enhancement of Ionospheric Ionization During Solar Flares », A. P. Mitra, R. E. Jones. Published in *J.A.T.P.*, Vol. 5, 104-106, May 1954.
5. « Theoretical and Experimental Study of the Recombination Coefficient in the Lower Ionosphere », A. P. Mitra, R. E. Jones. *Trans. I.R.E.-P.G.A.P.*, Vol. AP-2, 99-102, July 1952.
6. « Group Height Calculations in the Presence of the Earth's Magnetic Field », J. M. Kelso. *J.A.T.P.*, Vol. 5, 117, 131, July 1954.
7. « The Aeronomic Problem of Oxygen Dissociation », M. Nicolet. *J.A.T.P.*, Vol. 5, 132, 140, July 1954.

8. « The Attenuation of Alfven Waves », J. W. DUNGEY. *J.G.R.*, Vol. 59, Sept. 1954.

9. « Recombination in the Lower Ionosphere », A. P. MITRA, R. E. JONES. *J.G.R.*, Vol. 59, Sept. 1954.

10. « Atomic Nitrogen as a Constituent for Region F1 », A. P. MITRA. *Ind. J. Phys.*, Vol. 28, 269-284, June 1954.

11. « The Applicability of Continuous Fluid Theory in the Higher Atmosphere », D. G. YERG. *J. Meteo.*, Vol. 11, 387-391, Oct. 1954.

12. « Reflection of Waves by an Inhomogeneous Medium », V. A. BAILEY. *Phys. Rev.*, Vol. 96, 865-868, Nov. 15, 1954.

13. « Statistical Analysis of « 150-km » Echo », D. D. CHAFFEE, Jr. *J.G.R.*, Vol. 59, 549-550, Dec. 1954.

14. « The Development of an E-Region Model Consistent with Long Wave Phase Path Measurements », R. E. JONES. *J.A.T.P.*, Vol. 6, nº 1, 1-17, Jan. 1955.

15. « The Autocorrelogram of Randomly Fading Waves », R. B. BANERJI. *J.A.T.P.*, Vol. 6, nº 1, 50-56, Jan. 1955.

16. « Solar Electrodynamics », J. W. DUNGEY. *J.A.T.P.*, Vol. 6, nº 2, 88-90, March 1955.

17. « Viscosity on the High Atmosphere », D. C. YERG. *J.G.R.*, Vol. 60, nº 1, 87-94, March 1955.

18. « The Lower Ionosphere », A. H. WAYWICK. *Report of the Physical Society Conference on the Physics of the Ionosphere*, 1-13, 1955.

19. « M-Type Ionospheric Reflections at 150 kc/s », R. L. SCHRAG. *Report of the Physical Society Conference on the Physics of the Ionosphere*, 78-87, 1955.

20. « A method for Studying Large-Scale Irregularities in Region E of the Ionosphere », R. L. SCHRAG. *Report of the Physical Society Conference on the Physics of the Ionosphere*, 202-211, 1955.

21. « Electrodynamics of the Outer Atmosphere », J. W. DUNGEY. *Report of the Physical Society Conference on the Physics of the Ionosphere*, 229-236, 1955.

22. « Methods of Solving the Coupled Equations of Plane Wave Propagation in the Ionosphere », J. J. GIBBONS. *Report of the Physical Society Conference on the Physics of the Ionosphere*, 351-354, 1955.

23. « Instrumentation for the Continuous Measurement of Certain Ionospheric Echo Characteristics », R. W. PARKINSON. *Rev. Sci. Met.*, Vol. 26, 319-323, April 1955.

24. « An Electrical Polarization Synthesizer », G. H. FRIEDMAN. *Communications and Electronics* (*A.I.E.E.*), Vol. 1, 1-5, July 1955.

25. « Distribution-in-Speed of Fading of 150 kc/s Waves », R. B. BANERJI. *Nature*, Vol. 176, 131, July 16, 1955.

26. « The Effect of Vertical Ion Transport on the Night-time E-Region », H. R. PEIFFER, A. P. MITRA. *J.A.T.P.*, Vol. 6, nº 6, 291-303, June 1955.

27. « Diffusion Processes in the Thermosphere », P. MANGE. *Annales de Géophysique*, Vol. 11, nº 2, 153-168, April-June 1955.

28. « The Lunar Semi-Diurnal Oscillation in the Ionospheric Absorption of 150 kc/s Radio Waves », A. P. MITRA. *J.A.T.P.*, Vol. 7, nos 1-2, 99-100, Aug. 1955.

29. « The Aeronomic Problem of Nitrogen Oxides », M. NICOLET. *J.A.T.P.*, Vol. 7, nº 3, 152-169, Sept. 1955.

30. « Wave Solutions for Critical and Near-Critical Coupling Conditions in the Ionosphere », N. DAVIDS, R. W. PARKINSON. *J.A.T.P.*, Vol. 7, nos 4-5, 173-202, Oct. 1955.

31. « The Night-Time Lower Ionosphere as Deduced from a Theoretical and Experimental Investigation of Coupling Phenomena at 150 kc/s », R. W. PARKINSON. *J.A.T.P.*, Vol. 7, nos 4-5, 203-234, Oct. 1955.

32. « Meteor Ionization and the Night-Time E-Layer », M. NICOLET. « Meteors » (A Symposium on Meteor Physics) : Special Supplement (Vol. 2). *J.A.T.P.*, 99-110, 1955.

33. « Nitrogen Oxides and the Airglow », M. NICOLET. *J.A.T.P.*, Vol. 7, nº 6, 298-309, Dec. 1955.

34. « Some Exact Solutions of the Lorentz-Invariant Problem of the Motion of Two Electric Fluids », J. J. GIBBONS. *Can. Jour. of Phys.*, Vol. 33, nº 12, 819-823, Dec. 1955.

35. « Heights of Irregularities Giving Rise to the Fading of 150 kc/s Waves », R. G. BANERJI. *J.G.R.*, Vol. 60, nº 4, 431-439, Dec. 1955.

36. « The Fading Periods of the E-Region Coupling Echo at 150 kc/s », R. W. PARKINSON. Published in *J.A.T.P.*, Vol. 8, nº 3, 158-162, March 1956.

37. « 75 kc/s Pulsed Normal Incidence Ionospheric Sounding », A. J. FERRARO, J. J. GIBBONS, R. E. HOUSTON, W. J. ROSS, E. R. SCHMERLING. Published in *Proc. of Symposium on the Propagation of VLF Radio Waves*, NBS, Vol. 2, 13.1-13.7, Jan. 1957.

38. « Ionospheric Irregularities Causing Random Fading of Very Low Frequencies », S. A. BOWHILL. Published in *Proc. of Symposium on the Propagation of VLF Radio Waves*, NBS, Vol. 3, 28.1-28.10, Jan. 1957.

39. « The present State of Knowledge Concerning the Lower Ionosphere », A. H. WAYWICK. Published in *Proc. of Symposium on the Propagation of VLF Radio Waves*, NBS, Vol. 3, 43.1, Jan. 1957.

40. « Evaluation of the Part-Time Graduate Student Teacher », A. H. WAYNICK. Published in *Jour. Eng. Education*, Vol. 47, 589-592, March 1957.

41. « Some Effects of Intense Solar Activity on Radio Propagation », R. E. HOUSTON, W. J. ROSS, E. R. SCHMERLING. Published in *J.A.T.P.*, Vol. 10, 135-139, March 1957.

42. « Night-Time Ionisation in the Lower Ionosphere. I. Recombination Processes », A. P. MITRA. Published in *J.A.T.P.*, Vol. 10, 140-152, March 1957.
43. « Night-Time Ionization in the Lower Ionosphere. II. Distribution of Electrons and Positive and Negative Ions », A. P. MITRA. *J.A.T.P.*, Vol. 10, March 1957.
44. The present State of Knowledge Concerning the Lower Ionosphere », A. H. WAYNICK. Published in *P.I.R.E.*, Vol. 46, 741-749, 1957.

II*b*. — *Papers accepted for publication*

1. « The Aeronomic Problem of Helium », Marcel NICOLET. Accepted for publication in *Ann. de Geophys.*
2. « The Effect of Recorder Time Constant on the Apparent Speed of Fading of a Radio Signal », S. A. BOWHILL. Accepted for publication in *J.A.T.P.*
3. « A Circuit Setting Gate for Synchronizing Pulses », E. R. SCHMERLING. Accepted for publication in *Electronics.*
4. « Ionospheric Irregularities Causing Random Fading of Very Low Frequency », S. A. BOWHILL. Accepted for publication in *J.A.T.P.*
5. « The Theory of Molecular Diffusion in the Atmosphere », P. W. MANGE. Accepted for publication in *J.G.R.*
6. « The Calculation of Group Indices and Group Heights at Low Frequencies », J. J. GIBBONS, B. R. RAO. Submitted for publication in *J.A.T.P.*

III. — *U.R.S.I. papers*

1. « Methods of determining long wave reflection coefficients for a specific ionospheric model », J. D. WOLF, J. J. GIBBONS, Washington, D. C. May 1955.
2. « The amplitude and phase variations of 150 kc/s signals reflected from the E-layer », R. E. JONES, R. W. PARKINSON, Washington, D. C., May 1955.
3. « Heights of irregularities giving rise to fading of 150 kc/s waves », R. B. BANERJI, Washington, May 1955.
4. « Some direction-finding observations on travelling ripples in the ionosphere », J. W. Ross, Washington, D. C., April 1956.
5. « Methods of analysing fading records from spaced receivers », G. S. SALES, Washington D. C., April 1956.
6. « Fading of low frequencies and the double Gaussian correlogram », S. A. BOWHILL, Washington D. C., April 1956.
7. « The propagation of long waves near 100 kc/s over distances of the order 800 km », E. R. SCHMERLING, Washington, D. C., April 1956.

8. « Characteristics of ionospherically reflected vertically incident radio waves at 75 kc/s », R. E. HOUSTON, Jr., Washington D. C., April 1956.
9. « The polarization of vertically incident radio waves at 75 kc/s », J. J. GIBBONS, G. S. LEVY, S. R. BUTLER, Washington D. C., April 1956.
10. « The electron-density-height profiles in region F of the ionosphere », E. R. SCHMERLING, Washington, April 1956.
11. « The effect of various radiations on the E-layer of the ionosphere », R. E. HOUSTON, Jr., Washington, May 1957.
12. « Inclusion of the earth's magnetic field in a simple and rapid method for reducing *h'-f* curves to electron-density-height profiles », E. R. SCHMERLING, Washington, D. C., May 1957.
13. « Computation of group indices and group heights for low frequencies », J. J. GIBBONS, Washington, May 1957.

O. — RAMO-WOOLDRIDGE CORPORATION

III. — *U.R.S.I. papers*

1. « Calculation of the distribution of the electron density in the ionosphere », J. M. KELSO, Washington D. C., April 1956.
2. « Diurnal variations of signal level and scattering heights for VHF propagation », A. D. WHEELON, Berkeley, Oct. 1956.
3. « Bandwidth limitations of the ionosphere for through transmission », R. B. MUCHMORE, A. D. WHEELON, Berkeley, Oct. 1956.

P. — RAYTHEON MANUFACTURING COMPANY

III. — *U.R.S.I. papers*

1. « Long range meteoric echoes via F-layer reflections », W. A. WHITCRAFT, Jr., Washington, D. C., May 1955.
2. « Polarization fading over an oblique incidence path », D. A. HEDLUND, L. C. EDWARDS, Gainsville, Fla., Dec. 1955.
3. «An experimental investigation of ionospheric forward scattering at HF » D. A. HEDLUND, L. C. EDWARDS, Washington, D. C., May 1957.

Q. — SIGNAL CORPS ENGINEERING LABORATORIES

III. — *U.R.S.I. papers*

1. « Radioteletype transmission above the MUF », H. A. SCHULKE, Jr., Washington D. C., April 1956.

R. — Smyth Research Associates

III. — *U.R.S.I. papers*

1. « Some features of VLF propagation deduced from aircraft flight data », J. L. Heritage, Washington, D. C., April 1956.

S. — Stanford Research Institute

I. — *Activities*

Research in meteor burst propagation, systems, artic propagation and aurora.

III. — *U.R.S.I. papers*

1. « Some preliminary characteristics of meteor echoes as determined by radar investigations at frequencies of 100, 200 and 400 Mc », A. M. Peterson, Ray L. Leadabrand, Robert A. Rach, Washington, May 1957.
2. « On the diurnal changes of the optimum antenna bearings for meteor burst propagation : Part I, Measurements for n-s and e-w paths », A. M. Peterson, W. R. Vincent, Washington D. C., May 1957.

T. — Stanford University

I. — *Activities*

1. *Very low frequency propagation, including the « whistler » mode.* — An extension to high frequencies of Eckersley's dispersion law led to the discovery of a new phenomenon called the « nose » whistler. This was first identified in recordings made at College, Alaska, by the Geophysical Institute.

Identification of the « nose » effect is important because it provides information on the location of the path and the variation of ionization density along the path.

In cooperation with the NBS Boulder Laboratories, a study has been made of the lightening impulses which produce whistlers. It is found that they tend to be relatively lower in the audio frequency band than is the case with non-whistler-producing impulses.

A controlled whistler-mode experiment involving transmission between Annapolis, Maryland and Cape Horn, South America, has been performed successfully. Pulses at 15.5 kc/s were trans-

mitted from Station NSS and were received via both the ground-ionosphere path and by the whistler path. The results have confirmed Storey's whistler theory and provided new data on the characteristics of whistlermode signals.

VLF emissions, including hiss, dawn chorus, and other unusual signals, have been explained in terms of a travelling-wave amplification theory developed jointly by Gallet and Helliwell. It is hypothesized that the emissions are the result of selective travelling-wave amplification of noise energy present in the interplanetary medium. Energy for the amplification process is provided by streams of ionized particles which come from the sun and travel along the lines of the earth's magnetic field. The mechanism of amplification is similar to that of ordinary travelling tubes except that the « slow wave » circuit (provided by the helix of the tube) is the ambient ionization of the exosphere in the presence of the earth's magnetic field.

2. *Fundamental properties of radio reflections from Meteoric Ionization Trails.* — The directional properties of radio reflections from meteoric ion trails have been studied as a function of frequency in a spaced-transmitter experiment.

The length distribution of meteoric ionization trails has been investigated.

A theory has been developed which explains the fading of long-enduring meteor trails in terms of « glints », or specular reflections from small portions of an initially-straight trail distorted by the action of upper atmospheric winds. The theory relates the aspect sensitivity, diversity effect, fading speed change, reflected signal spectrum, rate distribution, delay to start of fade, and « Slow fade » phenomena to the statistical properties of the wind. The results confirm Whipple's photographically found winds, and exclude the presence of smaller scale turbulence in appreciable amplitude.

Progress has been made in the theoretical prediction of the initial size of meteoric ion trails. In general, the size is found to be larger than previously assumed. This fact may account for observations that back-scatter meteoric echoes at 100 megacycles are less numerous than would be predicted by a first order extension of the simple low-frequency theory.

3. *The Rate and Radiant Distributions of Meteoric Ion Trails.* — Studies of the rate of occurrence and the radiant distributions of the smaller meteor trails have shown that the greatest number of meteor reflections is obtained over a long propagation path when the antenna beams at each end are made to intersect somewhat to one side of the center of the great circle connecting transmitter and receiver. The best position for the volume illuminated by both antennas depends on the time of day and the direction and geographical location of the path. This information is of importance both in the design of communication circuits utilizing intermittent meteor reflections, and in the design of « ionospheric forward scatter » circuits utilizing a continuous signal. For the latter type of circuit, available evidence suggests strongly that at middle latitudes the meteoric component of the total signal is the strongest at all hours of the day except for a few hours around noon.

Rate and radiant measurements made with a 38 Mc/s rotating-beam radar have been used with good success to predict the optimum beam directions for a given oblique meteor-burst propagation path. Minor meteor showers, perhaps lasting an hour or two, have been discovered. Since such showers involve considerable meteoric activity from a single radiant, they can appreciably increase the number of reflections over an oblique path if the antenna beams are properly disposed. The correct position for these beams can be determined on a continuous basis, from the indications of a rotating-beam radar at one end of the path.

The information capacity of a forward-propagation « ionospheric scatter » circuit utilizing continuous transmission has been compared with the capacity of a comparable circuit when intermittent meteor burst propagation is utilized. It has been found that the information capacity falls off much more slowly with increasing frequency in the latter than the former case. This suggests the possibility of operating meteor burst communications systems at moderate power levels at frequencies in the 100-megacycle range, thus reducing both local interference and interference from distant stations propagated via the ionosphere.

4. *Long-distance radio reflections from auroral ionization.* — Echoes from ionization associated with auroral activity in the

auroral zone have been detected in the high frequency band at the relatively low geomagnetic latitude of Stanford, and have been under study for some time. Energy reaches the auroral zone in one hop when a suitable ionospheric tilt exists ; auroral echoes can also be detected when intermediate ground-ionospheric reflections take place. There is evidence that auroral ionization may be detected by sounding stations located anywhere on the earth, if intermediate reflections are utilized.

It is believed that ionization located over the auroral zone at E-region heights contributes most frequently to the echoes observed at a distance in this manner.

5. *Radio Reflections From Low-latitude Field-aligned Ionization.* — It has been discovered that radio echoes in the high frequency band may be obtained from ionization aligned with the earth's magnetic field at low geomagnetic latitudes. One class of echoes apparently occurs at E-region heights, and another at F-region heights. The E-region variety appears to be associated with the formation of Es ionization, and is seen at low latitudes as well as at high. The F-region variety apparently disappears as the sounding station is moved southward from the auroral zone. Neither of these effects is correlated with visible aurora or magnetic disturbance, although the echoes display a rapid fluctuation similar to that of radio echoes from auroral ionization.

6. *Studies of Sporadic E and of Tilts in the Ionosphere by the Ground Back-scatter Technique.* — Ground back-scatter mirrored in the ionosphere, has been used at Stanford to study the drift of individual clouds of sporadic E ionization. An extraordinarily high percentage of these clouds are found to drift from east to west, with an apparent speed of the same order of magnitude as that characteristic of ionospheric winds.

It has been found possible to observe, with simple scatter-sounding equipment, modes of ionospheric propagation which involve two or more successive reflections from the F-region without intermediate reflection from the ground. Ionospheric tilts are required to launch such modes, and to ensure the eventual return of the energy to the ground. Tilt-supported transmission is relatively strong, owing to focussing effects in the ionosphere and to the reduction of losses at the ground and in the D-layer.

The available evidence suggests that tilt-supported transmission is present for an appreciable fraction of the time, depending on ionospheric conditions and the location of the transmission path.

II. — *Published papers*

1. Eshleman, V. R. — « The Theoretical Length Distribution of Ionized Meteor Trails », *Journ. Atmos. and Terres. Physics*, Vol. 10, nº 2, pp. 57-72, Feb. 1957.
2. Clark, C., Peterson, A. M. — « Motion of Sporadic-E Patches determined from high-frequency back-scatter records », Letter to the Editor. *Nature*, Vol. 178, pp. 486-487, Sept. 1956.
3. Keitel, G. H. — « An extension of Milne's three-point method ». *Journ. of the Association for Computing Machinery*, Vol. 3, nº 3, July 1956.
4. Villard, Peterson, Manning, Eshleman. — « Some properties of oblique radio reflections from meteor ionization trails ». *Journ. Geophys. Res.*, Vol. 61, nº 2, pp. 233-249, June 1956.
5. Helliwell, Crary, Pope, Smith. — « The « Nose Whistler ». A new high-latitude Phenomenon ». *Journ. of Geophys. Res.*, Vol. 61, nº 1, pp. 139-142, March 1956.
6. Helliwell, Crary, Chase. — « Stanford-Seattle Whistler Observations ». *Journ. of Geophys. Res.*, Vol. 61, nº 1, pp. 35-44, March 1956.
7. Keitel. — « On the Dipole Resonant Mode of an Ionized Gas Column ». *Australian Journ. Phys.*, Vol. 9, nº 1, pp. 144-147, March 1956.
8. Peterson, Villard, Leadabrand, Gallagher. — « Regularly-Observable Aspect-Sensitive Radio Reflection from Ionization Aligned with the Earth's Magnetic Field and Located within the Ionospheric Layers at Middle Latitudes ». *Journ. of Geophys. Res.*, Vol. 60, nº 4, pp. 497-512, Dec. 1955.
9. Keitel. — « Certain Mode Solutions of Forward Scattering by Meteor Trails ». *Proc. I.R.E.*, Vol. 43, nº 10, pp. 1481-1487, Oct. 1955.
10. Villard, Eshleman, Manning, Peterson. — « The Role of Meteors in Extended-Range VHF Propagation ». *Proc. I.R.E.*, Vol. 43, nº 10, pp. 1473-1480, Oct. 1955.
11. Eshleman, Gallagher, Peterson. — Continuous Radar Echoes from Meteor Ionization Trails ». *Proc. I.R.E.*, Vol. 43, nº 4, p. 489, April 1955.
12. Eshleman. — « Theory of Radio Reflections from Electro-Ion Clouds ». *Trans. of I.R.E., Prof. Grp. on Antennas and Propagation*, Vol. AP-3, nº 1, Jan. 1955.
13. Van Valkenburg. — « The Two-Helix Method for Polarization Measurements of Meteoric Radio Echoes ». *Journ. of Geophys. Research*, Vol. 59, nº 3, pp. 359-364, Sept. 1954.

III. — *U.R.S.I. papers*

1. « Ionospheric Layer Heights », L. A. MANNING, Washington, D. C., May 1955.
2. « Theory of the Distribution of Meteor Trail Lengths », V. R. ESHLEMAN, Washington D. C., May 1955.
3. « The Role of meteoric ionization in extended-range VHF propagation », V. R. ESHLEMAN, L. A. MANNING, A. M. PETERSON, O. G. VILLARD, Jr., Washington, D. C., May 1955.
4. « The contribution of meteors to long-range back-scatter», P. B. GALLAGHER, A. M. PETERSON, Washington, D. C., May 1955.
5. « Simultaneous scatter-sounding observations of sporadic-E clouds at two separated locations », O. G. VILLARD, Jr., A. M. PETERSON, R. L. LEADABRAND, Washington, D. C., May 1955.
6. « The « Nose » Whistler. A new high-latitude phenomenon », R. A. HELLIWELL, J. H. CRARY, J. H. PAPE, R. L. SMITH, Gainsville, Fla., Dec. 1955.
7. « Regularly-observable aspect-sensitive radio reflections from ionization aligned with the earth's magnetic field and located within the ionospheric layers at middle latitudes », A. M. PETERSON, O. G. VILLARD, Jr., R. L. LEADABRAND, P. B. GALLAGHER, Gainsville, Fla., Dec. 1955.
8. « The communication possibilities of a new type of ionospheric scatter », A. M. PETERSON, O. G. VILLARD, Jr., Ray L. LEADABRAND, P. B. GALLAGHER, Washington, D. C., April 1956.
9. « The geometry of auroral communications », R. L. LEADABRAND, I. YABROFF, Washington D. C., April 1956.
10. « Methods of measuring ionospheric reflection coefficient using sweep frequency equipment », R. A. HELLIWELL, Washington, D. C., April 1956.
11. « The formation of sporadic E ionization and the recently discovered low latitude aspect sensitive ionization aligned with the earths magnetic field lines », R. L. LEADABRAND, A. M. PETERSON, O. G. VILLARD, Jr., Washington, D. C., April 1956.
12. « Evidence of a relationship between backscatter from field-aligned ionization in the F-layer, and fluctuations in the 5577A /01/ Airglow », O. G. VILLARD, Jr., S. STEIN, Washington, D. C., April 1956.
13. « A new whistler dispersion theory », R. A. HELLIWELL, T. F. BELL, R. L. SMITH, Washington D. C., April 1956.
14. « The application of nose whistlers to the study of the outer ionosphere », R. L. SMITH, Washington, D. C., April 1956.
15. « Radio echoes from auroral ionization detected at relatively low geomagnetic latitudes », R. L. LEADABRAND, A. M. PETERSON, Washington, D. C., April 1956.

16. « Experiments on whistlers and associated atmospherics », J. H. CRARY, R. A. HELLIWELL, Washington D. C., April 1956.
17. « Motion of Sporadic-E patches determined from high frequency backscatter records », C. CLARK, A. M. PETERSON, Berkeley, Oct. 1956.
18. « Lunar tidal variations in the sporadic-E layer of the ionosphere at Stanford, California », R. A. HELLIWELL, Berkeley, Oct. 1956.
19. « Some characteristics of equatorial F-region scattering deduced from soundings made aboard a moving ship », O. G. VILLARD, Jr., P. B. GALLAGHER, Berkeley, Oct. 1956.
20. « Nose whistler observations at Seattle », R. L. SMITH, R. A. HELLIWELL, Berkeley, Oct. 1956.
21. « On the interpretation of long-range radio echoes from auroral ionization », S. STEIN, O. G. VILLARD, Jr., Berkeley, California, Oct. 1956.
22. « The fading of meteoric radio echoes », L. A. MANNING, Washington, D. C., May 1957.
23. « On the diurnal changes of the optimum antenna bearing for meteor burst propagation : Part II, predictions based on theory and radar measurement of the meteor radiant distribution », V. R. ESHLEMAN, R. F. MLODNOSKY, Washington, May 1957.
24. « Radar Studies of meteors down to 15th Magnitude », P. B. GALLAGHER, V. R. ESHLEMAN, Washington, May 1957.
25. « Effects of ionospheric layer tilts on high frequency radio-propagation », S. STEIN, Washington, D. C., May 1957.

U. — SYRACUSE UNIVERSITY

III. — *U.R.S.I. papers*

1. « Sky wave propagation at low frequencies », Igor PLUSC, Gainsville, Fla., Dec. 1955.

V. — UNIVERSITY OF ALASKA

I. — *Activities*

Radio studies of the ionosphere were carried out at various frequencies ranging from ultra high to very low.

The effect of the terrestrial ionosphere upon UHF and VHF radio waves passing through it has been investigated using interferometer systems to study the signals from discrete radio sources at frequencies of 223 Mc/s and 456 Mc/s. The irregular variations in apparent intensity and in apparent source position, associated with periods of radio star scintillation, have both been investigated.

The backscatter of HF and VHF radio waves by aurora has

been studied at frequencies ranging from 12 Mc/s to 200 Mc/s. The aspect sensitivity was investigated using rotating antennas at 12, 50, and 100 Mc/s and showed that the radar echoes were most readily obtained when the radio waves were travelling almost perpendicularly to the magnetic field lines in the aurora. The aspect sensitivity was least marked at the lowest frequency. After allowing for the aspect sensitivity of the 100 Mc/s radar echoes, good correlation was found between the physical positions of the visual and radar aurora, although the visual brightness of the auroral form was no indication of the strength of the radar echoes from it. The Doppler shift of auroral echoes has also been studied. The frequency of the scattered signal was typically displaced relative to the transmitted frequency by up to a few hundred cycles per second. A first investigation suggested that the electron motions causing the Doppler shifts might be along the magnetic lines of force ; later work has shown that the motions are primarily horizontal and in the magnetic east-west plane, with velocities of the order of 1 km/sec.

High latitude ionospheric absorption has been studied using 30 Mc/s and 65 Mc/s extra-terrestrial radio waves. The absorption is typically greatest in the daylight hours and during equinoctial months. Nighttime absorption events correlate well with visual aurora, particularly with « flaming » or « pulsating » auroral forms. The absorption correlates well with periods of magnetic disturbance ; for a given degree of magnetic disturbance the absorption is considerably greater during the daylight hours than during the dark hours. This is probably due to the loss of electrons in the D region during the night by attachment, a process which would be countered by photo-detachment during the daytime. Absorption records taken simultaneously at Point Barrow and College, 800 km apart and inside and outside the auroral zone respectively, showed a correlation of 0.60 ; the median ratio of absorption between Point Barrow and College was 0.33. During disturbed periods, the absorption in db usually varies by at least a factor of two around a ring roughly 600 km in diameter, centered on College. The absorption is usually uniform over a 60° beam aimed at the zenith, though exceptions to this have been observed. A comparison of the attenuation of the extra-terrestrial signals with those from a local sweep frequency iono-

spheric sounder has shown that the large majority of the absorption of the extraterrestrial signal occurs below the E region maximum.

A review of ionospheric effects at VHF and UHF, prepared by Institute staff members, has also been published.

In the field of HF propagation the Geophysical Institute has continued its routine vertical incidence soundings of the ionosphere under a contract with the National Bureau of Standards. The occurrence and properties of the third magneto-ionic component on these soundings are under study.

An extensive experimental investigation of radio wave propagation via the ionosphere in and near the auroral zone which started in June 1949 was terminated in March 1957. This investigation included oblique incidence backscatter soundings at 12 Mc/s, observations of the forward scattering of these pulses, and continuous field intensity measurements of cw transmissions at 4, 8, and 12 Mc/s over 1100 and 350 km pathlengths across and along the auroral zone. Analysis of the cw transmission data has revealed that signal outages over the shorter paths, were caused by ionospheric absorption in at least 80 per cent, and probably 100 per cent, of all cases rather than by lack of ionization. The total time of signal outage was found to be greater during years of high solar activity than during years of low activity.

The pulse observations have shown that auroral ionization will cause aspect-sensitive backscatter from E-layer heights. Rapidly fading radio echoes may be received both by direct backscatter from auroral ionization above the radio horizon and by backscatter from clouds below the horizon with the outgoing and backcoming waves propagated via the E or F-layer. The latter long distance auroral echoes are generally reflected in the F layer during the daytime and the E layer during the night.

A program of HF transmission across the polar regions from Alaska to Norway was started in 1956 in cooperation with the Norwegian Defence Research Establishment. The first test transmission took place in July 1956 at the frequencies 6 and 12 Mc/s.

In the field of VLF ionospheric propagation observations of whistlers and « dawn » chorus have been made since July 1955. The whistler recordings lead to the discovery of the « nose-whistlers ». The occurrence of « dawn » chorus has been studied

with regard to daily and seasonal variation. It has been found that at the latitude of College, Alaska « dawn » chorus has its daily maximum at 14 hours LMT (geomagnetic noon) and an apparently linear relation between the time of the daily maximum and geomagnetic latitude has been established. There appears to be a seasonal variation in the correlation between the daily occurrence of « dawn » chorus and the daily magnetic K-index. For the solsticial months a positive correlation coefficient of about 0.5 is obtained while the equinoctial months give a numerically equally large but negative correlation coefficient between the two phenomena.

II. — *Published papers*

1. K. L. Bowles. — « Doppler Shifted Radio Echoes from Aurora ». *J. Geophysical Research.* Vol. **59**, 553-555, 1954.
2. S. Chapman, C. G. Little. — « The Non-deviative Absorption of High Frequency Radio Waves in Auroral Latitudes ». *J. Atmos. and Terres. Phys.*, Vol. **10**, pp. 20-31, 1957.
3. R. B. Dyce. — « Auroral Echoes Observed North of the Auroral Zone on 51.9 Mc/s ». *J. Geophys. Res.*, Vol. **60**, pp. 317-323, 1955.
4. R. A. Helliwell, J. H. Crary, J. Y. Pope, R. L. Smith. — « The « Nose » Whistler — a New High Latitude Phenomenon ». *J. Geophys. Res.*, Vol. **60**, pp. 139-142, 1956.
5. C. G. Little. — « High Latitude Ionospheric Observations Using Extra-Terrestrial Radio Waves ». *Proc. I.R.E.*, Vol. **42**, pp. 1700-1701, 1954.
6. C. G. Little, W. M. Rayton, R. B. Roof. — « Review of Ionospheric Effects at VHF and UHF ». *Proc. I.R.E.*, Vol. **44**, pp. 992-1018, 1956.
7. B. Nichols. — « Drift motions of auroral ionization ». In publication. *J. Atmospheric and Terr. Phys.*

III. — *U.R.S.I. papers*

1. « Aurora Borealis studied using VHF radio echoes », K. L. Bowles, Washington, D. C., May 1955.
2. « Observations of the geographical position and extent of regions of anomalous high-latitude absorption », H. Leinbach, C. G. Little, Washington, D. C. May 1957.
3. « 398 Mc Auroral echoes observed at College, Alaska », A. M. Peterson, R. L. Leadabrand, R. B. Dyce, Washington, D. C., May 1957.

W. — University of California at Los Angeles

III. — *U.R.S.I. papers*

1. « Electron distribution in a new model of the ionosphere », H. K. Kallmann, Washington, D. C. May 1957.

X. — University of Maryland

I. — *Activities*

1. *Rockets.* — Much of our effort has been devoted to making rocket research cheaper and easier. In particular it should become adaptable to university research and to routine investigations of the ionosphere. For this purpose we have developed and fired three types of sounding rockets : (i) an aircraft launched 2.75 inch rocket whose cost is only $ 50 (exclusive of aircraft) ; (ii) a simple ground launched rocket whose cost is approximately $ 200 ; and (iii) a more elaborate ground launched rocket capable of carrying a substantial payload whose cost is approximately $ 2000. This latter rocket is being improved to enable it to reach altitudes of over 1 million feet. Up to the present time our work has been devoted to preparing instrumentations and ground station equipment and the publications have been concerned primarily with techniques rather than results. Some of these publications are listed in the references.

2. *Magnetic Storms and Correlated Effects.* — An effort has been made to develop a model of magnetic storms which takes account of the fact that the region around the earth is not a vacuum but instead a very good electrical conductor. A magnetohydrodynamic model of magnetic storms has therefore been worked out which accounts for the first time for the reverse sudden commencement and attempts to give a theory of the sudden commencement. Separately, a theory of the ring current has been worked out which leads to a stable ring current and allows for the first time a calculation of the spatial distribution of the ring current around the earth. Its connection with the aurora has been investigated and some crucial experiments have been planned for the Geophysical Year. Correlated with magnetic storms there are certain cosmic ray effects which give us a clue to the electromagnetic state of the environment of the earth and of the interplanetary space.

A theory has been developed for these so-called Forbush decreases of cosmic rays which often occur during magnetic storms. A modification of this theory explains the low energy cutoff of the cosmic ray spectrum which acts an as indicator of the state of turbulence of the interplanetary gas.

3. *Applications of Earth Satellites.* — Much work has been done to demonstrate the utility of satellites for geophysical research and a major review paper has been published covering many of these geophysical applications. It appears that even a minimum satellite, carrying only a few pounds of instrumentation, can give very valuable data which will help settle many crucial problems concerning not only the ionospheric layers but also the earth's interior, the lower atmosphere, as well as the state of the outer ionosphere. The list of publications gives an idea of the range of applications considered.

II. — *Published papers*

1. « Investigation of the Solar Corona by Means of Rockets », in «Rocket Exploration of the Upper Atmosphere », p. 371, Pergamon Press, 1954.
2. « Rocket Exploration of Magnetic Fields and Electric Currents in the Upper Atmosphere», p. 256, Pergamon Press, 1954.
3. « The Exploration of the Upper Atmosphere with Rockets », a chapter in Vistas in Astronomy, Pergamon Press, 1957.
4. « A Method for Calculating Impact Points of Ballistic Rockets ». *Jet Propulsion*, **27**, 407, April 1957.
5. « The Terrapin Rocket — A Vehicle for Synoptic Upper Atmosphere Soundings », a chapter in High Altitude Sounding Rockets, McGraw-Hill, 1957.
6. « Terrapin — An Upper Atmosphere Research Vehicle ». *Jet Propulsion*, **2**, 281, 1957.
7. « Rockair — A Promising New Tool for Specialized High Altitude Research. *Jet Propulsion*, March 1957.
8. « Terrapin — the do it yourself rocket ». *Missiles and Rockets*, Vol. 2, nº 3, p. 60, March 1957.
9. « Review of Recent Developments in Geophysical Aspects of Cosmic Rays ». *American Geophysical Union Report for I.U.G.G. Congress*, Sept. 1954.
10. « A New Method of Measuring the Low-Energy Spectrum of Primary Cosmic Rays ». *Phys. Rev.*, **98**, 1547, 1955.

11. « A New Model of Magnetic Storms and Aurorae ». *Trans. Am. Geophys. Union*, **38**, 175, 1957.

12. « Trapped Orbits in the Earth's Dipole Field ». *Bull. Am. Phys. Soc.*, Series II, **1**, 229, 1956.

13. « The Primary Cosmic Radiation and its Time Variations », in Progress in Cosmic Ray and Elementary Particle Physics, Interscience, New-York, 1957.

14. « Cosmic Ray Time Variations Produced by Deceleration in Interplanetary Space ». *Nuovo Cim.*, Suppl. 1957.

15. « On the Low Energy Cutoff of the Cosmic Radiation ». *Nuovo Cim.*, Suppl. 1957.

16. « Observations of Cosmic Ray Decreases at the Pole ». *J. Geophys. Res.* March 1955.

17. « Astrophysical Measurements from an Artificial Earth Satellite », in Rocket Exploration of the Upper Atmosphere, p. 368, Pergamon Press, 1954.

18. « Studies of a Minimum Orbital Satellite of the Earth », Part I. « Geo physical and Astrophysical Application ». *Astron. Acta*, 1, 171, 1955. Part II. « Orbits and Lifetimes of Minimum Satellites ». *Astron. Acta*, 2, 125, 1956. Part III. « Radiation Problems and Temperatures ». *Astron. Acta*, 3, 1957.

19. « Application of an Artificial Satellite to the Measurement of the General Relativistic « Red Shift ». *Phys. Rev.*, 104, 11, 1956.

20. « Measurements of the Earth's Magnetic Field from a Satellite Vehicle », in *Scientific Uses of Earth Satellites*, Univ. of Mich. Press, 1956.

21. « Measurements of Interplanetary Dust », in *Scientific Uses of Earth Satellites*, Univ. of Mich. Press, 1956.

22. « The Effect of Meteoric Particles on a Satellite », *Jet Propulsion*, **26**, 1071, 1956.

23. « Radioactive Meteor Erosion Gauge for Earth Satellites », for Nuclear Technology Conference, 1957.

24. « Minimum Earth Satellites as « Storm Patrol ». *Scientific Monthly*, 1957.

25. « Geophysical Research with Artificial Earth Satellites », Chapter in Advances in Geophysics, Vol. 3, Academic Press, Inc., New-York, 1956.

26. « A Method for the Determination of the Vertical Ozone Distribution from a Satellite ». *J. Geophys Research*, June 1957.

27. « Meteorological Measurements from a Minimum Satellite Vehicle ». *Trans. Am. Geophys. Union*, **38**, 1957.

III. — *U.R.S.I. papers*

1. « Magnetic Storm Effects in the Inner and Outer Ionosphere », S. F. Singer, Washington, D. C., May 1957.

Y. — University of Michigan

III. — *U.R.S.I. papers*

1. « Spatial areas of Fade Resulting from Ionospheric Polarization Rotation », Irving B. Goldberg, Washington, D. C., May 1957.

Z. — University of Puerto Rico

III. — *U.R.S.I. papers*

1. « Study and Interpretation of Low Angle Fluctuations From the Radio Star Cassiopeia as Observed at Ithaca, New-York », B. Dueno, Washington, D. C., April 1956.

AA. — U. S. Naval Research Laboratory

I. — *Activities*

The Naval Research Laboratory work on ionospheric research has taken advantage of high-altitude sounding rockets. Flights have been made up to 263 km, mostly at White Sands, New Mexico. Measurements have included electron density profiles, differential absorption, positive and negative ion composition, neutral gas composition, air pressure and density, and the intensity of various ultraviolet and soft x-ray bands. Electron density profiles have also been compared with ground measurements.

Similar measurements will be made during the International Geophysical Year, but emphasis will be placed on making the measurements in the Arctic and during unusual solar or auroral activity. The results of the recently completed pre-I.G.Y. program are now being prepared for publication.

II. — *Published papers*

1. Jackson, Kane, Seddon. — *Jour. Geophys. Res.*, Dec. 1956.
2. Jackson. — *Jour. Geophys. Res.*, Sept. 1954.
3. Seddon, Picker, Jackson. — *Jour. Geophys. Res.*, Dec. 1954.
4. Seddon. — *Jour. Geophys. Res.*, Dec. 1954.
5. Seddon, Jackson. — *Phys. Rev.*, 97, n° 4, Feb. 1955.
6. Seddon, Jackson. — *Ann. de Geophys.*, April 1955.
7. Johnson, Heppner. — *Jour. Geophys. Res.*, Dec. 1955.
8. Johnson, Heppner. — *Jour. Geophys. Res.*, Sept. 1956.

9. Meadows, Townsend. — *Jour. Geophys. Res.*, Sept. 1956.
10. Horowitz, LaGow. — *Jour. Geophys. Res.*, March 1957.
11. Byram, Chubb, Friedman. — *Jour. Geophys. Res.*, June 1956.
12. Byram, Chubb, Friedman. — *Phys. Rev.*, 98, June 1955.
13. Friedman. — *Ann. de Geophys.*, April-June 1955.
14. Jackson. — *Jour. Geophys. Res.*, March 1956.

III. — *U.R.S.I. papers*

1. « A new Method for Obtaining Electron Density Profiles from P′-*f* Records », John E. Jackson, Gainsville, Fla., Dec. 1955.
2. « Solar control of the Ionosphere », H. Friedman, Washington, D. C., April 1956.
3. « The D and Lower E-region », J. C. Seddon, Washington D. C., April 1956.
4. « A Recent NRL Rocket Measurement of Ionospheric Electron Densities », J. A. Kane, J. E. Jackson, Washington D. C., May 1957.
5. « Differential Absorption in the D and Lower-E Regions », J. Carl Seddon, Washington D. C., May 1957.

AB. — University of Washington

III. — *U.R.S.I. papers*

1. « The Formation of Sporadic E Ionization and the Recently Discovered Low Latitude Aspect Sensitive Ionization Aligned with the Earth's Magnetic Field Lines », H. M. Swarm, Washington D. C., April 1956.

AC. — Wittenburg College

III. — *U.R.S.I. papers*

1. « The Clustering of Meteor Bursts at Twenty Megacycles Over a 608 kilometer Path », Lloyd R. Wylie, Washington D. C., May 1957.

AD. — Wright Air Development Center

III. — *U.R.S.I. papers*

1. « The Clustering of Meteor Bursts at Twenty Megacycles over a 608 kilometer Path », Horace T. Castillo, Washington, May 1957.

Summary of the address of Dr. D. F. Martyn, Chairman of Commission III

at the Plenary Opening Session

Dr. Martyn compared the ionosphere to a series of mirrors at different heights, each capable of reflecting radio waves of different lengths.

The first technical session of Commission III would be devoted to the lowest mirror, which existed at heights below 100 km, and the introductory paper to this session would be given by Professor A. H. Waynick whose laboratory at State College Pennsylvania had been responsible for so much of our recent knowledge of this subject.

The ionospheric mirrors were not symmetrical about the earth, nor even about the geographic equator. They bulged to greater heights near the magnetic equator and generally showed a remarkable dependence on magnetic latitude. A discussion on this topic would be introduced by Sir Edward Appleton who had made important studies of this aspect in the post-War years.

The ionospheric mirrors were subject to disturbances associated with storms on the sun. At such times they were changed in height and reflecting power according to complex patterns which depended upon latitude, longitude and season. A session on this topic would be introduced by Professor K. Maeda of Japan, a country which had made notable contributions to our knowledge of these effects.

The ionospheric mirrors moved both up and down, and sideways. Professor L. G. H. Huxley would introduce a session on such movements, which had been intensively studied in Australia.

The mirrors were not perfect; their surfaces were rough and radio waves were scattered from these irregularities, whose origins were not yet fully explored. Professor H. G. Booker would

introduce a session on this topic, to which he had made notable contributions.

The great solar flare of 23rd February, 1956, had profoundly affected the ionospheric mirrors in unusual ways. A discussion on this topic would be opened by Mr. A. H. Shapley, who would outline many of the unusual occurrences associated with this flare.

The ionospheric mirrors posed one serious problem to the ground radio experimenter : it was hard to « see » above them. It was also important to know how these mirrors were made, and in what gases of the atmosphere they were embedded. A great advance had been made in post-War years by the use of rockets to carry measuring instruments of many kinds directly up into and through the mirrors. The U. S. Naval Research Laboratories had been responsible for much of this work and Dr. Freidmann of these Laboratories would introduce a session on this topic.

For many years it has been known that « atmospherics » are electromagnetic impulses radiated by lightning flashes. Atmospherics are specially strong on long radio wavelengths such as are confined between the earth and the lowest ionospheric mirror. A particular type of atmospheric gives a musical tone of descending pitch, aptly called a « whistler ». Since the war it had been discovered at Cambridge, U. K., that whistlers too were due to lightning flashes, and that their unusual musical properties arose from the fact that they had penetrated all the ionospheric mirrors and travelled many thousands of kilometers beyond them, guided by the curved lines of the earth's magnetic field. This topic was important to Commissions III, IV, and V, and a combined session would be held under the chairmanship of Mr. J. A. Ratcliffe, in whose laboratory many of the properties of whistlers had been elucidated.

Minutes of the Sessions

Meeting of Official Members :
Friday, 23 August 1957

Present : Dr. D. F. MARTYN, *Chairman*,
Dr. Y. AONO (for Prof. K. Maeda),
Dr. O. BURKARD,
Dr. W. DIEMINGER,
Dr. D. C. ELLYETT (for Mr. J. Burtt),
Father F. E. GALDON (for Dr. J. Elias),
Dr. S. GEJER,
Mr. A. HAUBERT,
Dr. M. G. MORGAN,
Dr. M. NICOLET,
Dr. I. RANZI (for Prof. M. Boella),
Dr. W. J. G. BEYNON, Secretary,
Mr. D. LÉPÉCHINSKY, Secretary.

1. — *Sub-Commissions.*

The proposals of the Executive Committee concerning Sub-Commissions were considered. It was agreed that all existing Sub-Commissions of Commissions III should be dissolved at the end of the present Assembly.

Modifications and additions were proposed to the draft rules for Sub-Commissions which had been received from the Executive Committee.

2. — *Status of Deputies for Official Members of Commissions.*

It was agreed that the Executive Committee should be asked to clarify the status of deputies for official members of Commissions.

3. — *Organization of Symposia Between General Assemblies.*

The proposal of the Executive Committee for holding symposia at intervals of about one year on specific topics within the field

of one or more Commissions was considered. The Commission expressed general agreement with the proposal, but decided that in view of the heavy commitments of workers concerned with the I.G.Y. program it was undesirable to organise symposia on topics likely to involve such workers before 1959. It was agreed, however, that U.R.S.I. should, at an early date, make known its plans for organising such symposa after the conclusion of the I.G.Y. The Commission agreed that topics pertaining to I.G.Y. ionospheric results should be referred for consideration by the U.R.S.I.-A.G.I. Committee.

Technical Sessions

The Minutes of the various Sessions have been divided into two sections :

I. Discussion of Ionospheric Topics.

II. Administrative Matters.

I. — Ionospheric topics

Eight discussion sessions were held and a list of the topics considered, together with the names of the introductory speakers, is given below :

« The lower ionosphere », Professor A. H. Waynick,

« Geomagnetic distorsion in the ionosphere » Sir Edward Appleton,

« Ionospheric storms » Professor Kenichi Maeda,

« Ionospheric movements » Professor L. G. H. Huxley,

« Ionospheric scattering » Professor H. G. Booker,

« Geophysical events associated with the Solar Flare of 23 February, 1956 » Mr. A. H. Shapley,

« Rocket studies of the upper atmosphere » Dr. Friedmann,

« Whistlers and related VHF phenomena » Mr. J. A. Ratcliffe (Joint session with Commissions IV and V).

II. — Administrative Matters

Administrative matters were considered at three sessions and the minutes of these are given below.

Monday 26 *August* 1957.

1. — *Sub-Commissions.*

(i) The Commission received the proposals of the Executive Committee concerning Sub-Commissions and agreed that at the end of the present Assembly, the four Sub-Commissions of Commission III should be dissolved. It was further agreed that proposals for the continuation of any Sub-Commission, or for the formation of new Sub-Commissions, should be made to the Commission, prior to submission to the General Assembly (see also minute 7).

(ii) Reports of Sub-Commissions :

(*a*) *Sub-Commission IIIa* : « Ionospheric observations and reduction of data ». — The Chairman of the Sub-Commission (Mr. A. H. Shapley) reported that this Sub-Commission had been formed at Sydney in 1952 but had not functioned satisfactorily and its work had, in fact, been later taken over by the U.R.S.I.-A.G.I. Committee.

(*b*) *Sub-Commission IIIb* : « Ionospheric Wave Interaction ». — The report of M. Picault, which had been included in the papers of Commission III, was accepted.

(*c*) *Sub-Commission IIIc* : « Study of propagation times of radio signals ». — No report had been received from this Sub-Commission, but a memorandum had been received from a member of the Sub-Commission (Professor Koga).

(*d*) *Sub-Commission IIId* : « Magneto-ionic nomenclature ». — Mr. Ratcliffe (*Chairman*) reported that the findings of this Sub-Commission had been published in the *U.R.S.I. Information Bulletin.* The Commission accepted the report and suggested that after approval by the General Assembly, it should be submitted by the U.R.S.I. General Secretary to the principal radio and geophysical journals.

It was also agreed to invite Professor L. G. H. Huxley to prepare a document giving the formulae in rationalised units, this to be published at the same time as the original report.

(*e*) *Permanent Sub-Commission on Ursigrams.* — Dr. Lépéchinsky (deputising for Father Lejay) presented a report on the activities of the Ursigram Sub-Commission.

(iii) Rules for Sub-Commissions. — The Commission discussed proposals for rules for Sub-Commissions, received from the Executive Committee and suggested certain modifications.

2. — *Status of Deputies.*

The Commission considered the status of deputies for Official Members and referred the question to the Executive Committee for its consideration.

3. — *Working Parties.*

(i) Ionospheric Index of Solar Activity. — The Commission received the proposal from the Mixed Commission on the Ionosphere for the development of an ionospheric index of solar activity and appointed the following to consider and report on the matter, during the present Assembly : Dr. W. J. G. Beynon (*Chairman*), Dr. D. H. Menzel, Mr. A. H. Shapley.

(ii) C.C.I.R., Study Programme n° 26 : *Ionospheric sounding stations after the I.G.Y.* — The following Working Party was appointed to consider this question : Mr. D. K. Bailey (*Chairman*), Mr. A. H. Shapley, Mr. F. T. Davies, Dr. Y. Aono, Dr. Lépéchinsky, Dr. W. Dieminger. (Further reference to C.C.I.R. Problems is made under minute 4).

Tuesday, 3rd September, 1957.

4. — *Problems referred to Commission III by C.C.I.R.*

Considerable discussion took place on the best method of dealing with problems referred to Commission III by C.C.I.R. It was finally agreed that Commission III should establish a Committee consisting of the President of the Commission and the two Secretaries. This Committee will function between General Assemblies and will be empowered to deal with all C.C.I.R. problems referred to Commission III, consulting other experts as required, and whenever possible will endeavour to supply an authoritative answer to the problems concerned. The reply from this Committee will be communicated to the U.R.S.I.-C.C.I.R. Committee for transmission to C.C.I.R.

It was agreed that a notice calling attention to this decision should be inserted in the *U.R.S.I. Information Bulletin.*

5. — *Proposal for a Permanent International Ionospheric Service.*

The Commission discussed the proposal for the establishment of a permanent international ionospheric service. The subject was introduced by Father P. LEJAY and a recommendation for the discussion of this subject had also been submitted by the Mixed Commission on the Ionosphere. Father LEJAY emphasised that with the vast increase in the volume of ionospheric data during the I.G.Y., it has become very desirable to organise the collection and dissemination of the data on international lines in the manner already achieved for certain other geophysical data.

The C.S.A.G.I. Ionosphere Reporter (Dr. BEYNON) outlined the manner in which the four I.G.Y. Ionosphere Data Centres had been established and stated that an Advisory Committee on the operation of these Centres had in fact been nominated. This Advisory Committee, consisting of representatives of the four Centres concerned, together with the C.S.A.G.I. Reporter as Chairman, seemed to be the nucleus out of which, after the I.G.Y., an International Ionosphere Service might grow.

The Commission agreed that the C.S.A.G.I. Advisory Committee on Ionosphere World Data Centres was an appropriate body to consider the post-I.G.Y. operation of the Data Centres, and that U.R.S.I. should express to this body its interest in the creation of an International Ionosphere Service after the conclusion of the I.G.Y.

Wednesday, 4th September, 1957.

6. — *Reports of Working Parties.*

(i) IONOSPHERIC INDEX OF SOLAR ACTIVITY. — The Chairman (Dr. BEYNON) reported that the Working Party had given some preliminary discussion to the problem and proposed that a Sub-Commission be formed to consider it more fully. The Commission agreed to the formation of a Sub-Commission with the following membership : Dr. W. J. G. BEYNON (*Chairman*), Dr. D. H. MENZEL, Mr. A. H. SHAPLEY, Professor C. W. ALLEN and Mr. C. M. MINNIS.

The Commission authorised the Sub-Commission to issue provisional indices a soon as agreement on such indices can be reached.

(ii) C.C.I.R. STUDY PROBLEM N° 26 : *Ionospheric sounding stations after the I.G.Y.* — The Report of this Working Party

was presented by Mr. D. K. BAILEY, and is given in Appendix I to these Minutes.

7. — *Sub-Commissions.*

The Commission agreed on the following action concerning the various Sub-Commissions.

(i) SUB-COMMISSION III*a* : *Ionospheric observations and reduction of data.* — It was agreed that most of the work of this Sub-Commission was currently being done by the World Wide Sounding Sub-Committee of the U.R.S.I.-A.G.I. Committee (see Minute 1.ii (*a*)). In the circumstances the Commission recommended that Sub-Commission III*a* should temporarily be dissolved, the position to be reviewed at the next General Assembly.

(ii) SUB-COMMISSION III*b* : *Wave Interaction.* — The Commission recommended that this Sub-Commission be now dissolved.

(iii) SUB-COMMISSION III*c* : *Study of propagation times of radio signals.* — The Commission considered that the work of this Sub-Commission would be of interest to certain I.G.Y. studies and that the Sub-Commission should continue in being.

(iv) SUB-COMMISSION III*d* : *Magneto-ionic nomenclature.* — This Sub-Commission had completed its task and the Commission recommended its dissolution (see Minute 1,ii (*d*)).

(v) PROPOSALS FOR NEW SUB-COMMISSION ON « IONOSPHERIC INDICES OF SOLAR ACTIVITY ». — The Commission agreed to establish a new Sub-Commission with the membership and terms of reference given in Minute 6 (i) above.

8. — *Proposal for U.R.S.I. Special Report.*

The Commission discussed possible subjects for U.R.S.I. Special Reports and it was agreed to propose to the General Assembly that a Special Report on « Radio Observations of the Aurora » be prepared by a Committee with the following membership : Dr. J. H. CHAPMAN, (*Chairman*), Professor A. C. B. LOVELL, Dr. A. M. PETERSON, Mr. OWREN, Professor H. G. BOOKER, Dr. ELLYETT and Dr. L. HARANG.

9. — *Proposals for Symposia and Joint Study Group.*

(i) SYMPOSIA. — The Commission received the proposal of the Executive Committee for the organisation of Symposia at approxi-

mately yearly intervals, and proposed the following two topics for consideration :

(*a*) The outermost ionosphere.

(*b*) Geophysical events associated with the solar flare of 23rd February, 1956.

(ii) JOINT STUDY GROUP. — Arising principally from discussions during the session on ionospheric scattering and ionospheric movements, the Commission considered that progress towards a solution of certain ionospheric problems urgently calls for collaboration between workers in the fields of electro-magnetics, hydromagnetics and fluid mechanics. Accordingly the Commission recommends that in the near future, workers in these fields be invited to participate in a joint Study Group at which such problems shall be examined. It is not considered that this sort of problem is suitable for a Symposium on conventional lines but rather that experts in the fields named should be brought, together for a period of severals weeks to work on the actual problems. It was agreed that proposals for such a Joint Study Group should be formulated forthwith (see Resolution 10).

10. — *Resolutions.*

Nine Resolutions formulated by the Mixed Commission on the Ionosphere at its meeting in New-York in August 1958, were presented at the Session and adopted by Commission III. (A full list of Commission III Resolutions is given on p. 171).

Meeting of Special Committee on World-Wide Soundings

on August 29, 1957

The following members of WWSC, principal consultants and members of former Special Committee on high latitudes were present : Y. Aono, K. Rawer, A. Haubert, R. W. Knecht, J. W. Wright, K. Davies, as well as observers from different nations.

Three major points were discussed :

I. — Future Work of WWSC

The changes introduced by previous recommendation of WWSC concern the general philosophy as well as details of scaling and accuracy rules. In order that those changes be as efficient as possible, it seems worthwhile that the committee continue its action as a monitoring committee during I.G.Y. The following points have been noted as especially interesting :

1. General application of the new rules, use of characteristics and letters, reading accuracy.

Material : Published tables, data sheets and *f*-plots.

2. « Common feeling » in those cases where some judgement is implied at scaling. Especially for characteristics *fo*F1, *fo*Es and « type of Es ».

Material : ionograms of world days, etc.

3. Accuracy of :

— time of records ;

— frequency markers ;

— frequency sweep (constancy of scale, camera speed and continuity) ;

— height markers (frequency, zero point) ;

— height sweep (constancy, linearity).

Some of these points can be checked (*a*) by use of ionograms, (*b*) others by statistical methods.

(*a*) Ionograms may be used for checking the frequency sweep, the zero point of height markers, the height sweep.

(*b*) Appropriate statistical methods are e. g. : probability distribution of numerical readings, solar controlled effects on the equation of time, sunrise effects, the seasonal variation, etc.

Material :

ionograms of world days,

data sheets,

monthly medians.

The material should be available at least at the world-data-centers.

It has been recommended that members and principal consultants should be specialized as members for different topics and methods.

In the case where substantial inaccuracies or errors are stated the organization in question should be informed by the chairman of the WWSC.

A special report on some accuracy checks will be prepared by J. W. Wright and R. M. Gallet.

The following recommendations should be forwarded to Commission III :

A. Ionosondes should be so adapted and regularly controlled that a maximum of technical accuracy is obtained.

B. Ionograms should be recorded in such a way that, apart from actual scaling, more accurate scaling methods may be applied to these records in the future.

II. — Experience With the New Scaling Rules

Generally speaking all organizations represented have good experience with the new rules and apply them in a regular manner for routine work. Some minor difficulties are reported, especially with respect to E*s* (see III). Aono thinks that the exchange of *f*-plots in original form (paper copies) should be preferred to Micro copies on 35 mm film. It is reported that Turner has some comments to the accuracy of median.

III. — Detail Questions concerning the scaling rules

It is stated that the Brussels statement, that the F2 layer corresponds always to the highest stratification in the F-region should be precized such that in the case where the F2 layer disappears behind the F1 layer. The F-trace should not be identified with F2. The wording of Brussels intended only to cover F-stratifications such as F1.5.

The following detail questions are put on the agenda of a next meeting :

Knecht : Scaling of h'E, f_oE, f_bE*s* with equatorial E*s*,

Knecht : Scaling of f_bE*s*, f_oE*s* with a gap on the frequency axis,

Aono : Scaling of f_bE*s* if the extraordinary component goes to lower frequencies,

Haubert : Use of letters if no blanketing is observed,

Haubert : Median values qualified by E or D,

Rawer : Scaling of f_oE*s*, f_bE*s* when no E*s* trace is present,

Rawer : Median in this case,

Rawer : Accuracy of f_oF1 and last digit to be used.

Comments on C.C.I.R. Resolution n° 26

IONOSPHERIC SOUNDING STATIONS AFTER I.G.Y.

(Report of a Working Group)

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1. The C.C.I.R. in Resolution n° 26 of the VIIth Plenary Assembly of Warsaw, 1956, has drawn the attention of U.R.S.I. to the desirability of continuing in operation after the I.G.Y. certain of the ionospheric stations specially established or continued in operation solely for the I.G.Y. programme. The objective from the C.C.I.R. viewpoint is to improve propagation forecasts.

2. From the U.R.S.I. viewpoint continued operation of certain I.G.Y. ionospheric sounding stations after the I.G.Y. would also be desirable for filling gaps in the present knowledge of ionospheric morphology and disturbances.

3. In many respects the objectives stated above may be regarded as identical.

4. The U.R.S.I. therefore recommends that as many as possible of the following stations be continued in operation preferably on a 15 minutes basis for not less than one year after the next minimum of the solar cycle.

Arctic	*Antarctic*	*Equatorial*	*Gap Fillers*
Alert	South Pole	Natal	Tamanrasset
Thule	Little America	Talara	St. Johns
Svalbard	Terre Adelie	Bogota	Mexico City
Tromsö	Halley Bay	La Paz	Concepcion

Arctic	*Antarctic*	*Equatorial*	*Gap Fillers*
Bukhta Tikhaya	Syowa (Showa)	Djibouti	Tahiti
Tiksi Bay	and/or Mawson	Kodaikanal	Sao Paulo
Providenie Bay		Bangui	Tucuman
		Davao	Kerguelen Is.
			Macquarie Is.
			Marion Is.

---

(1) This location is not certain. It is understood that the Philippine Government plans an I.G.Y. station at a location to the south of Manila nearly on the magnetic equator.

Summary of Remarks by Dr. D. Martyn Chairman of Commission III

at Closing Session of U.R.S.I.

Dr. Martyn summarised the technical and administrative sessions of Commission III, made recommendations regarding Sub-Commissions and U.R.S.I. Special Reports, and for certain symposia and a joint study group.

The full text of the resolutions and recommendations of his Commission are given on p. 171-174.

Resolutions and Recommendations

The following nine Resolutions formulated by the Mixed Commission on the Ionosphere at its Meeting in New-York (August, 1957), were subsequently endorsed by U.R.S.I. at the XIIth General Assembly at Boulder.

1. *Ionospheric Current Systems* :

(i) The MCI expresses the hope that new determinations of the Sq and S_D electric current systems in the ionosphere will be made on the basis of the IGY magnetic records.

(ii) The MCI invites the International Association of Geomagnetism and Aerology (I.A.G.A.) to consider the possibility of determining the latitudes of the foci of the Sq current systems at one or more longitude on as many days as possible during the I.G.Y.

2. *Region E parameters.* — The MCI reaffirms its earlies resolutions on the need for accurate scaling and timing of region E parameters. It recommends that recordings of the E-region trace on ionograms should be made on expanded frequency scales. It further recommends that special attention should be given to the measurement of $h'E$ at stations located near the magnetic equator.

3. *Ionospheric Tidal Phenomena.* — The MCI calls attention to the need for studies during the I.G.Y. of lunar tidal-oscillations in the E and sporadic E layer parameters — $h'E$, fE, $h'Es$.

4. *Height and Frequency Scales of Ionograms.* — The MCI recommends that during the I.G.Y., the U.R.S.I. World Soundings Sub-Committee should be charged with the control of relative and absolute scales of height and frequency.

5. *Measurements of horizontal ionospheric movements.* — The MCI recommends that there should be the fullest co-operation

between stations studying horizontal movement so that the world pattern of such motion may be elucidated.

6. *Electron density/height profiles* (N, *h*). — The MCI recommends that organisations which undertake the calculation of N, *h* profiles should interchange sample ionograms and the corresponding calculated profiles, so as to ensure agreement on the results obtained by different methods.

7. *Rocket investigations in Auroral latitudes.* — The MCI recommends that a more intensified small rocket programme should be carried out in auroral latitudes to study particle and other radiation at levels below 90 km.

8. *Ionospheric irregularities.* — The MCI recommends that groups observing rapidly moving ionospheric irregularities should be encouraged to continue this work and to interchange results. It is also strongly recommended that studies of all ionospheric movements should be arranged on a local or regional basis.

9. *Nomenclature.* — The MCI recommends :

(i) that the total ionisation content per unit column in that part of an ionised region below its peak be designated the « sub-peak electron content » of the region.

(ii) that the present terminology on « whistlers » (« nose-whistlers» etc.), should be regarded as tentative and that a study of a more appropriate terminology should be immediately undertaken.

(iii) that the letter A be used to designate auroral ionization resulting directly or indirectly from the entry into the earth atmosphere of solar particles : also that the subdivisions of this ionisation be indicated as follows :

A*a* auroral ionisation due to primary atomic particles ;

A*e* auroral ionisation due to electrons ;

A*x* auroral ionisation due to X-radiation ;

A*u* auroral ionisation due to ultra-violet radiation ;

A*r* auroral ionisation due to photo-detachment by red radiation.

The General Assembly also adopted the following Resolutions :

10. *Proposal for Joint Study Group.* — Recognising the inter-relation that exists in the ionosphere between electro-magnetics,

hydro-magnetics and fluid mechanics, Commission III recommends that encouragement be given to a Joint Study by workers in fluid mechanics and in geophysics, with a view to encouraging, on the one hand, the solution by fluid mechanics workers of unsolved problems in geophysics, and encouraging, on the other hand, the application in geophysics of established knowledge in fluid mechanics.

11. *Rocket and Satellite Experiment.* — Commission III of U.R.S.I. encourages member countries to undertake Rocket and Satellite programmes of the atmosphere and of the surrounding regions of space and urges collaboration between nations engaged in such enterprises.

12. *Analysis of I.G.Y. Data.* — If the full benefit of the I.G.Y. Programme is to be realised, it is necessary to make provision for extended studies of the data by qualified workers. U.R.S.I. strongly urges those Government agencies which have financed the prosecution of the I.G.Y. programme now to allocate adequate funds for the purpose of supporting scientists wishing to analyse the data obtained.

13. *Symposia.* — Commission III of U.R.S.I. welcomes and endorses the proposal of the Executive Committee to hold Symposia on special topics of radio science at approximately yearly intervals. Bearing in mind however, that most scientists and organisations working on ionospheric radio are heavily involved in I.G.Y. activities until the end of 1958, and consequently have no time to prepare such Symposia successfully, it is proposed that no Symposia on matters concerning Commission III shall be held before the middle of 1959.

14. *Theoretical Studies of Electron density/height profiles.* — Whilst recognising the great advances which have been made in the calculation of electron density/height profiles U.R.S.I. now recommends that the theoretical problem in its widest sense (including anisotropy and collision of electrons) of the determination of the distribution of ionisation with height should be further studied. It is part of this problem to specify precisely what information, measurable at the ground, is needed for the unique theoretical determination of the distribution. The general

study would also be of value for further investigations of the troposphere.

15. *Sub-Commissions.* — Commission III recommends :

(i) that Sub-Commission III*a* on Ionospheric Observations and Reduction of Data, Sub-Commission III*b* on Wave Interaction, and Sub-Commission III*d* on Magneto-ionic Nomenclature be dissolved.

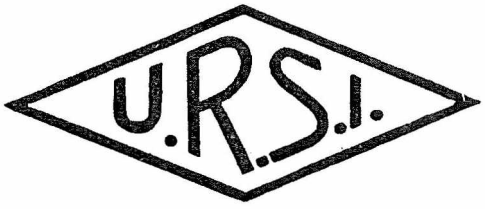
(ii) that Sub-Commission III*c* on Study of Propagation Time of Radio Signals continue in being under the chairmanship of Prof. Boella and with the same membership.

(iii) that a new Sub-Commission III*e* on Ionospheric Indices of Solar Activity be established under the Chairmanship of of Dr. W. J. G. Beynon and with the following membership : Dr. D. H. Menzel, M. A. H. Shapley, Professor C. W. Allen and M. C. M. Minnis.

16. *Special Report.* — Commission III recommends that a Special Report on « Radio Observations of the Aurora » be prepared by a Committee with the following membership : Dr. J. H. Chapman (*Chairman*), Professor A. C. B. Lovell, Dr. A. M. Peterson, M. Owren, Prof. H. G. Booker, Dr. Ellyett and Dr. L. Harang.

17. U.R.S.I. expresses its high appreciation of the manner in which the Central Radio Propagation Laboratory of the National Bureau of Standards has assisted scientific research on the ionosphere and allied topics in many centres throughout the world by its skilled assembly of data and its friendly readiness to furnish such data to « bona fide » scientific workers in other lands. U.R.S.I. is of the opinion that the production and publication of the Laboratory's F-Series publication has indeed been a major factor in facilitating the advance of our basic knowledge of the ionosphere and of the factors which influence its variations.

INTERNATIONAL SCIENTIFIC RADIO UNION



Proceedings of the XIIth General Assembly

held in Boulder, Colorado, U. S. A.
from August 22nd to September 5th, 1957

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COMMISSION IV

On Radio Noise of Terrestrial Origin

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COMMISSION IV

On Radio Noise of Terrestrial Origin

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United States of America : Mr. Um. Q. CRICHLOW, National Bureau of Standards, Boulder, Col.

U. S. S. R. : Prof. N. M. IZYUMOV, c/o Academy of Sciences, Moscow.

Yugoslavia : Prof. Ing. A. DAMIANOVITCH, Faculté d'Electrotechnique, 6, Stevana Sremca, Beograd. 2.

List of Reports and Papers submitted to the Commission

The asterisk indicates reports published in this part.

E = Original text in English
F = Original text in French

N°	Titles and Authors
1	C.C.I.R. Findings of interest to the U.R.S.I. (E).
3	Periodic dawn chorus, H. E. DINGER (E).
4	The computation of ionospheric reflection coefficients from the waveforms of sferics, A. G. JEAN, L. J. LANGE, J. R. WAIT (E).
36	Field-changes due to the lightning discharges and their discharge mechanisms, H. KITAGAWA (E).
37	Lightning mechanisms and radiation atmospherics, H. ISIKAWA (E).
38	The waveform of atmospherics in the Far East, A. KIMPARA (E).
39	Some results of simultaneous measurements of atmospheric noise in high frequency band, A. KIMPARA, H. SHINKAWA, T. FUJITA, Y. AONO, Y. TAKI, F. MINOZUMA (E).
40	Measurement of amplitude probability distribution of atmospheric noise in high frequency band, T. ISHIDA (E).
41	On an investigation of whistling atmospherics in Japan, A. KIMPARA, A. IWAI, J. OUTSU (E).
115	Waveform studies of electric field-changes during cloud-to-cloud lightning discharges, B. A. P. TANTRY, R. S. SRIVASTAVA, S. K. KHASTGIR (E).
125*	Report of the British National Committee to Commission IV, F. HORNER (E).
126	Atmospheric radio noise at frequencies between 10 kc/s and 30 kc/s, J. HARWOOD (E).

N°	Titles and Authors
127	The relation between atmospheric radio noise and lightning, F. HORNER (E).
141*	Report of the Swiss National Committee to Commission IV, Prof. J. LUGEON (E) (F).
151	The use of magnetic tape recording for studying atmospheric noise structure, C. CLARKE (E).
159*	Report of the New Zealand National Committee to Commission VI (E).
170*	Report of the Morocco National Committee to Commission IV (F).
193*	Report of the German National Committee to Commission IV, A. EHMERT (E).
200*	Report of the Japanese National Committee to Commission IV, A. KIMPARA (E).
211*	Report of the French National Committee to Commismission IV (F).
216*	Report of the Swedish National Committee to Commission IV, H. NORINDER (E).
224*	Report of the Australian National Committee to Commission IV (E).
229	Variation forms and time sequence of multiple lightning strokes, H. NORINDER, B. VOLLMER (E).
230	Pre-discharges in relation to subsequent lightning strokes, H. NORINDER, E. KNUDSEN (E).
231	Atmospheric electric discharges from distant snow squalls and occlusion front, H. NORINDER, E. KNUDSEN (E).
239	Lightning discharge channel characteristics and related atmospherics radio interference, M. M. NEWMAN (E).
240*	Report of the Polish National Committee to Commission IV (E).
254*	Report of a Sub-Commission (E).
267	Results obtained recently regarding the mechanism of lightning discharges, H. NORINDER (E).
292	Whistlers and associated phenomena, R. A. HELLIWELL (E).
298*	Report of U.S.A. Commission IV (E).

N° 254 — Report of Subcommisson on the Question :

What are the Most Readily Measured Characteristics of Terrestrial Radio Noise from which the Interference to Different Types of Communications Systems can be Determined

prepared by William Q. CRICHLOW

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I. — INTRODUCTION

A subcommittee was formed within Commission IV at the XIth General Assembly to study the question « What are the Most Readily Measured Characteristics of Terrestrial Radio Noise from which the Interference to Different Types of Communication Systems can be Determined ». This committee was delegated to study the question by correspondence and to submit a report at the XIIth General Assembly. Contributions have been received from representatives of the Union of South Africa, the United Kingdom, Japan, France, and the United States of America. Acting as chairman of this committee, I have attempted to summarize these

contributions and have also included additional discussion relative to work done in India, Canada, and Australia.

The basic limitation to the reception of a radio signal is the noise with which it must compete. For this reason, detailed studies of the interference characteristics of the noise are necessary. There are two basic reasons for providing information on the level and characteristics of radio noise. The first reason concerns existing radio systems. With an existing radio system, it is necessary to determine the weakest possible signal that will provide satisfactory service in the presence of noise. The second reason for providing information on noise characteristics is so that improved circuits can be engineered to minimize the influence of noise upon reception. The solution of both of these basic problems is made extremely difficult by the variable nature of the level and characteristics of the noise.

Although there are many types of noise that cause interference to reception, this study has been directed toward atmospheric noise which is the principal source of interference at frequencies below about 30 Mc/s. This type of noise which originates in thunderstorms existing throughout the world, is very erratic in character and varies over wide limits as a function of a number of variables ; the principal ones being the geographic location, the radio frequency, time of day, and season. Some of these variations are systematic, and some are of a random nature and must be treated statistically. It is convenient to separate the variations with time into intervals of various lengths. Let us consider first the short term variations.

During periods of several minutes to about an hour, the statistical properties of atmospheric noise remain essentially constant. These have been described by several investigators using amplitude time distributions. This type of presentation is most convenient for investigating the interference caused by a particular type of noise to an existing communication service, as well as for designing new systems to operate in the presence of a give type of noise.

From hour to hour during the day, both the level and shape of the distribution will change because of changing propagation conditions and frequency of thunderstorms, but fortunately these variations tend to follow a particular pattern. At the lower frequencies, the nighttime noise level is high because noise is propa-

gated by means of the ionosphere from storms at large distances. During the daytime, the ionospheric absorption is high and the noise received from distant storms is reduced, the received noise being principally from local storms. Local storms tend to predominate during the afternoon hours, and therefore the noise level is enhanced somewhat during these hours. Thus, we have maximum noise levels at night, minimum during the morning, a moderate increase in the afternoon, and again high levels at night. At the higher frequencies, the shape of the diurnal curve tends to reverse itself because the ionosphere will support propagation only during the daylight hours.

From day to day, at a particular time of day, there are variations in the received noise level due to variations in propagation conditions and in thunderstorm activity. These day to day variations can also be conveniently treated by means of amplitude-time distributions, just as in the case of the instantaneous values.

There is also a systematic seasonal trend to the noise that is influenced by ionospheric absorption as well as the location and number of thunderstorms. The thunderstorm centers tend to shift above and below the equator from summer to winter, and in addition the ionospheric absorption is higher in the summer which tends to offset the increased thunderstorm activity at that time. Nevertheless, the received noise tends to be highest in the summer and lowest in the winter at tropical and temperate latitudes.

The received noise level varies with frequency, because the noise radiated by the thunderstorm and its efficiency of propagation are functions of frequency. In general, the received noise level decreases with increased frequency.

There are variations in the noise level with geographic location, the highest levels being encountered in equatorial regions, and the lowest levels in the polar regions. The received noise levels are influenced by topography, as well as weather and propagation conditions. There are also variations in received noise levels with sunspot activity.

II. — Measured Characteristic of Atmospheric Noise

This section consists of a summary of recent measurements made in various countries. The measurements made are quite varied and have been subdivided into types of measurement.

A. — *Subjective Measurements*

All of the subjective measurements reported were made by the so-called Thomas method of measurement where a locally generated low speed telegraph signal is mixed with the noise and its level is manually adjusted so that the estimated intelligibility is 95 %.

1. *United Kingdom.* — Measurement of this type have been continued at high frequencies (2-20 Mc/s) as part of the program of the Radio Research Station at several locations distributed over the world. Measurements have also been made at low frequencies (15-500 kc/s) at some of the stations.

2. *France.* — Measurements with Thomas type equipment were compared with measurements of the average envelope voltage and were reported to agree within 3 db.

3. *Japan.* — Thomas type measurements were made in Japan by the Kokusai Densin Denwa Company. The measurements were made over the range of frequencies 5-15 Mc/s and also in the broadcast band. The results are shown in Fig. 1.

4. *Australia.* — Measurements have been made by the Thomas method at Rockbank and at Pierce over the frequency range 2.5-20 Mc/s.

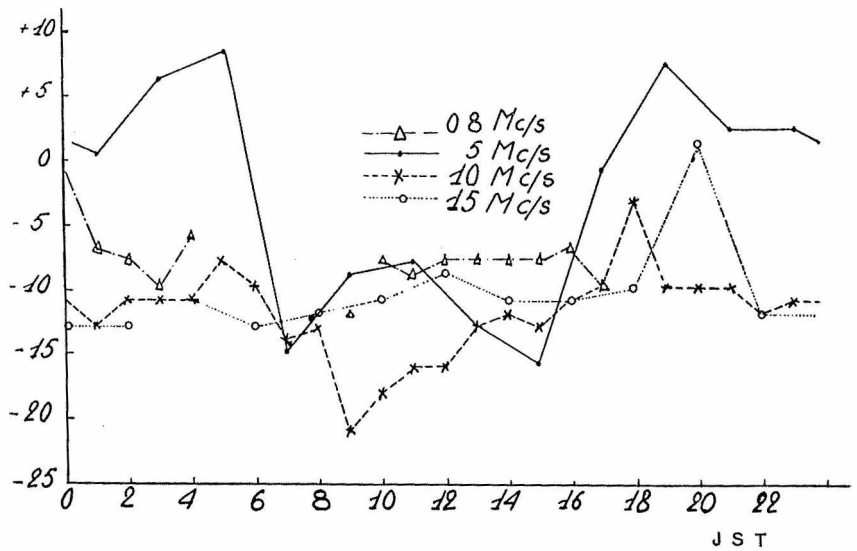


Fig. 1. — Atmospheric noise field intensity measured by Thomas method.

5. *United States of America.* — Thomas measurements have been made by the U. S. Signal Corps at Balboa, Panama Canal Zone for a number of years on frequencies from 2.5-20 Mc/s.

B. — *Average Measurements*

The average value of the noise envelope voltage has been measured extensively in all of the countries on the committee.

1. *Union of South Africa.* — Measurements of average noise were made in South Africa by the Telecommunications Research Laboratory at frequencies of 100 kc/s, 500 kc/s, and 8 Mc/s, and the levels were recorded on film. The bandwidth was about 5 kc/s per second, and the AGC voltage of the receiver was continuously recorded on film. The time constants involved were charge, 0.5 seconds and discharge, 1.5 seconds. The recorded value thus being slightly higher than the true average value in most types of atmospheric noise.

2. *United Kingdom.* — Measurements of the average envelope voltage have been made at the Radio Research Station at frequencies of 10 kc/s and 30 kc/s using a bandwidth of 300 cycles per second. From all the data, the best estimates have been of the median values for different times of day and seasons of the year. These are given in Table I.

TABLE I

Average field strength of noise envelope in μV/m in a bandwidth of 300 c/s

Frequency	Season	Time of Day (Hrs)					
		00-04	04-08	08-12	12-16	16-20	20-24
10 kc/s	Dec., Jan., Feb.	65	55	35	35	60	80
	Mar., Apr., May	80	45	45	65	80	90
	June, July, Aug.	160	100	110	200	200	180
	Sept., Oct., Nov.	140	110	70	110	160	180
30 kc/s	Dec., Jan., Feb.	30	22	13	11	16	30
	Mar., Apr., May	40	18	16	25	25	45
	June, July, Aug.	70	35	40	70	55	70
	Sept., Oct., Nov.	50	40	22	35	35	50

3. *France.* — Recordings of average noise field strength have been made on the following frequencies in kc/s : 187, 60, 27, 12.5, 8.6, 5.3, 4.3, 2.3. The bandwiths were of the order of 100 c/s. A time constant of the order of a minute is produced either mechanically or electrically. The results of measurements on 27 kc/s during 1954 and 1955 are show in Fig. 2.

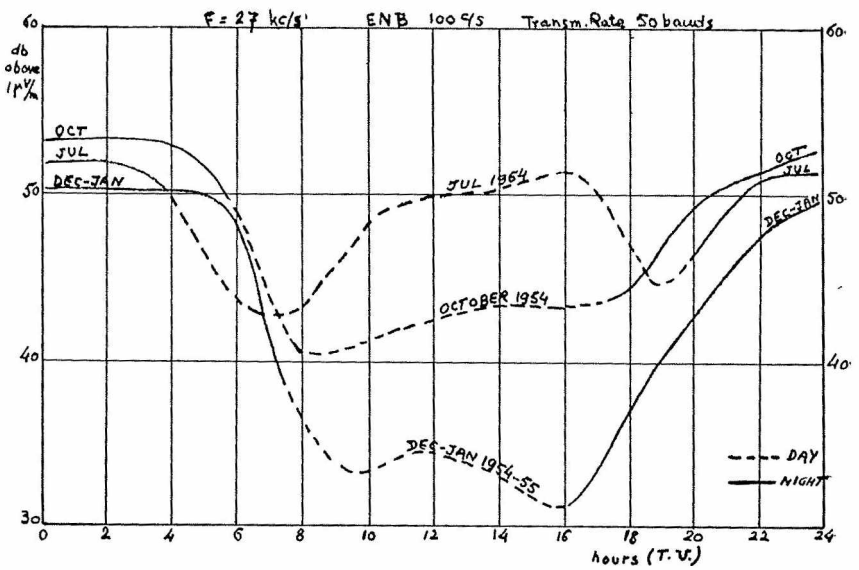


Fig. 2. — Minimum field strength for A. M. radioteletype reception. Monthly mean levels 1954-1955, Paris

4. *Japan.* — Measurements of average noise have been made by the Radio Regulatory Bureau and NHK on frequencies of 5, 10, and 15 Mc/s using a bandwidth of 1.78 kc/s. The detector charge and discharge time constants were 10 microseconds, and the meter time constant was 600 milliseconds.

5. *United States of America.* — Continuous recordings have been made for a number of years by the National Bureau of Standards at Front Royal, Virginia and Boulder, Colorado covering the frequency range from 135 kc/s to 20 Mc/s, Bandwidths from 200 c/s to 1000 c/s have been used, and the charge and discharge time constants have been of the order of 3 minutes.

Similar recordings have also been made at the University of Florida over the frequency range 15 kc/s to 530 kc/s, using a bandwidth of about 1000 cycles.

Measurements of this type have also been made by the Federal Communications Commission, the U. S. Signal Corps, and the U. S. Air Force.

C. — *Quasi-Peak*

Quasi-Peak measurements have been made in several countries using a standard charging time constant of 10 milliseconds and a discharge time constant of about 600 milliseconds. In general, the measurements were made with the same equipment that was used to make the average measurements.

1. *Japan.* — Measurements were made in Japan by NHK and RRB at ten locations throughout the country. Measurements were made for two weeks every season at 4 frequencies ranging from 2 to 20 Mc/s. Typical results of these measurements are shown in Fig. 3.

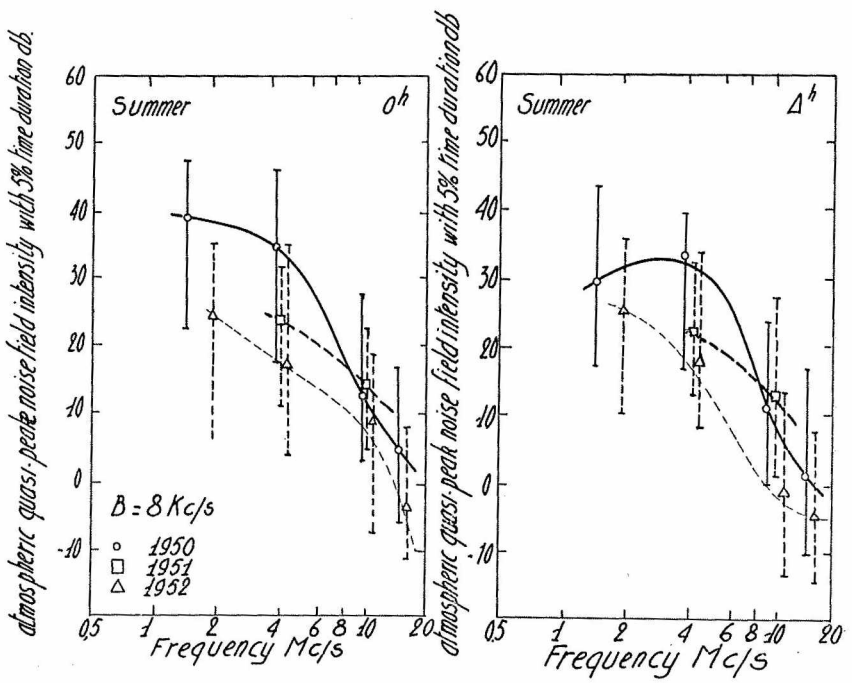


Fig. 3.

2. *United States of America.* — Measurements of this type have been made in the past by the Federal Communications Commission and the U. S. Air Force.

3. *India.* — Measurements of the quasi peak value of atmospheric noise have been made by the College of Engineering at Posna, India over the frequency range 1 to 20 Mc/s using a bandwidth of 6 kc/s. The audio-frequencies were fed through a logarithmic amplifier to a recording vacuum tube voltmeter having a charging time constant of 10 milliseconds and a discharging time constant of 500 milliseconds. The results of measurements during the hours 18 to 24 (IST) are given in the following table — values estimated from thunderstorm activity are also given.

TABLE I

Comparison of Observed and Estimated Noise Field Strengths

f in Mc/s	Source dist. (km)	N° of months	Mean Observed Value in μV/m	Estimated Value in μV/m
2.9	700	8	10.6	13.0
2.9	1500	1	6.2	9.2
2.9	2000	3	5.3	7.3
2.9	4000	4	0.9	2.3
4.7	700	9	7.3	8.1
4.7	1500	3	5.2	5.7
4.7	2000	2	4.4	4.5
4.7	4000	3	0.9	1.4

D. — *R.M.S. Voltage*

Measurements of the r.m.s. voltage or mean power have been made by several countries; however, not as extensively as some of the other types of measurements. This parameter was recommended by the C.C.I.R. several years ago and gained some favor at that time.

1. *Union of South Africa.* — The r.m.s. value was determined by the Telecommunications Research Laboratory by numerically integrating film recordings of the instantaneous noise voltage on frequencies of 100, 500 kc/s and 8 Mc/s.

2. *France.* — R.M.S. values were determined in France from photographic recordings of the voltage from a thermocouple in the last I. F. tuned circuit.

3. *United Kingdom.* — The r.m.s. value was derived at the Radio Research Station from more detailed statistical measurements.

4. *Japan.* — Measurements were made at NHK using an effective value meter whose characteristics were square law over the linear range of the I. F. output.

5. *United States of America.* — Measurements of average noise power have been made by the National Bureau of Standards over the frequency range 50 kc/s to 20 Mc/s at Boulder, Colorado and Bill, Wyoming using an electronic square law circuit in the I. F. system. Continuous recordings have been made at these locations for over a year, and typical results are shown in Fig. 4. These measurements were made with a bandwidth of 300 cycles and a time constant of 500 seconds.

The equipment used was developed by NBS and is being manufactured in quantities such that sixteen stations are to be in operation throughout the world during the International Geophysical Year.

E. — *Mean Logarithm*

Measurements of the mean logarithm of the noise envelope voltage have been made in two countries. In both cases, the instantaneous detector voltage was applied at the input of a logarithmic amplifier that responded to the instantaneous variations. The output of this amplifier was then averaged and applied to a recording meter.

1. *Canada.* — Measurements were made by the Radio Physics Laboratory on 10 kc/s at Ottawa, Ontario over a period of 1 year beginning in October 1955. Measurements were also made at Churchill, Manitoba on a frequency of 107 kc/s for the period December, 1955 to August, 1956. The results are shown in Fig. 5.

2. *United States of America.* — Measurements of the mean logarithm were made by the National Bureau of Standards at Boulder, Colorado over the frequency range 50 kc/s to 20 Mc/s through a bandwidth of 300 c/s and using a time constant of 50 seconds. Records over a six-months period have been obtained to date.

F. — *Direction of Arrival Measurements*

Measurements to determine the direction of arrival of atmospheric radio noise have been made in the United Kingdom at the

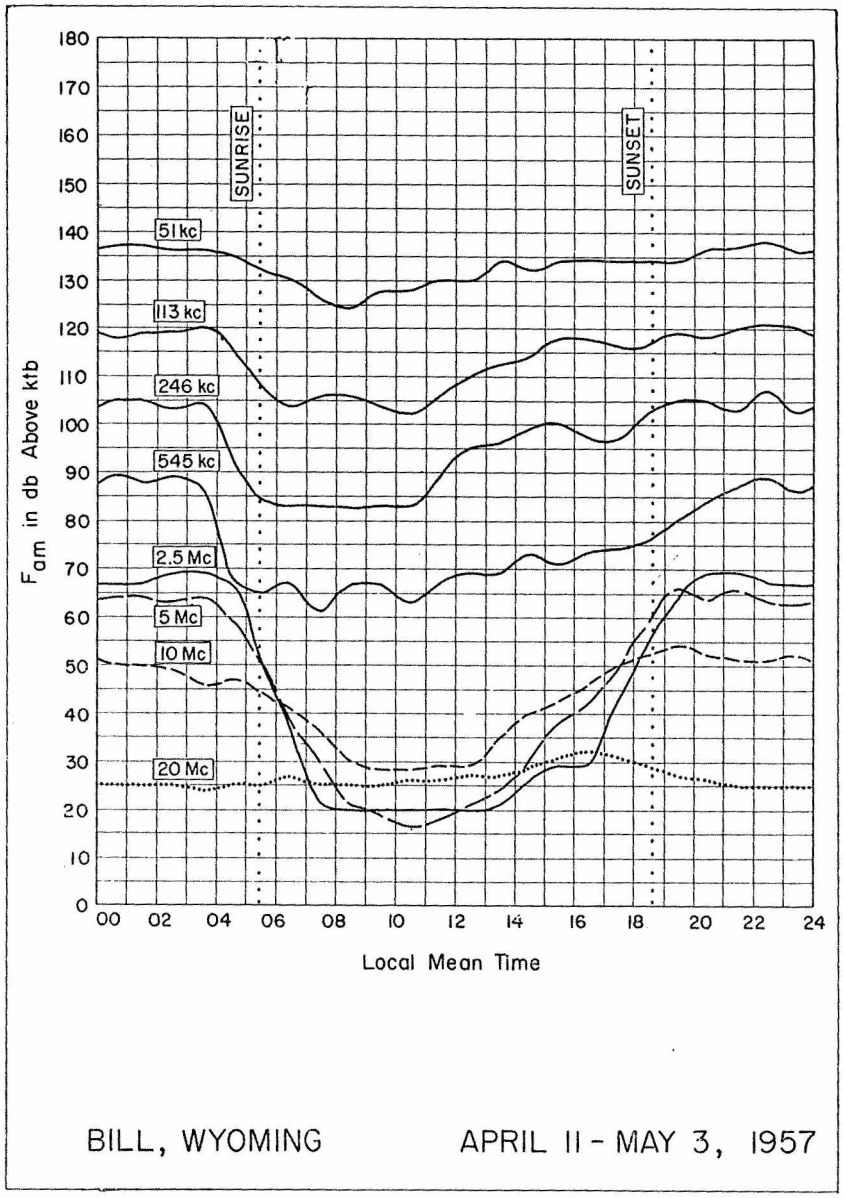

180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
SUNRISE
SUNSET
51 kc
113 kc
246 kc
545 kc
2.5 Mc
5 Mc
10 Mc
20 Mc
F_{am} in db Above ktb
00 02 04 06 08 10 12 14 16 18 20 22 24
Local Mean Time
BILL, WYOMING
APRIL 11 - MAY 3, 1957

Fig. 4.

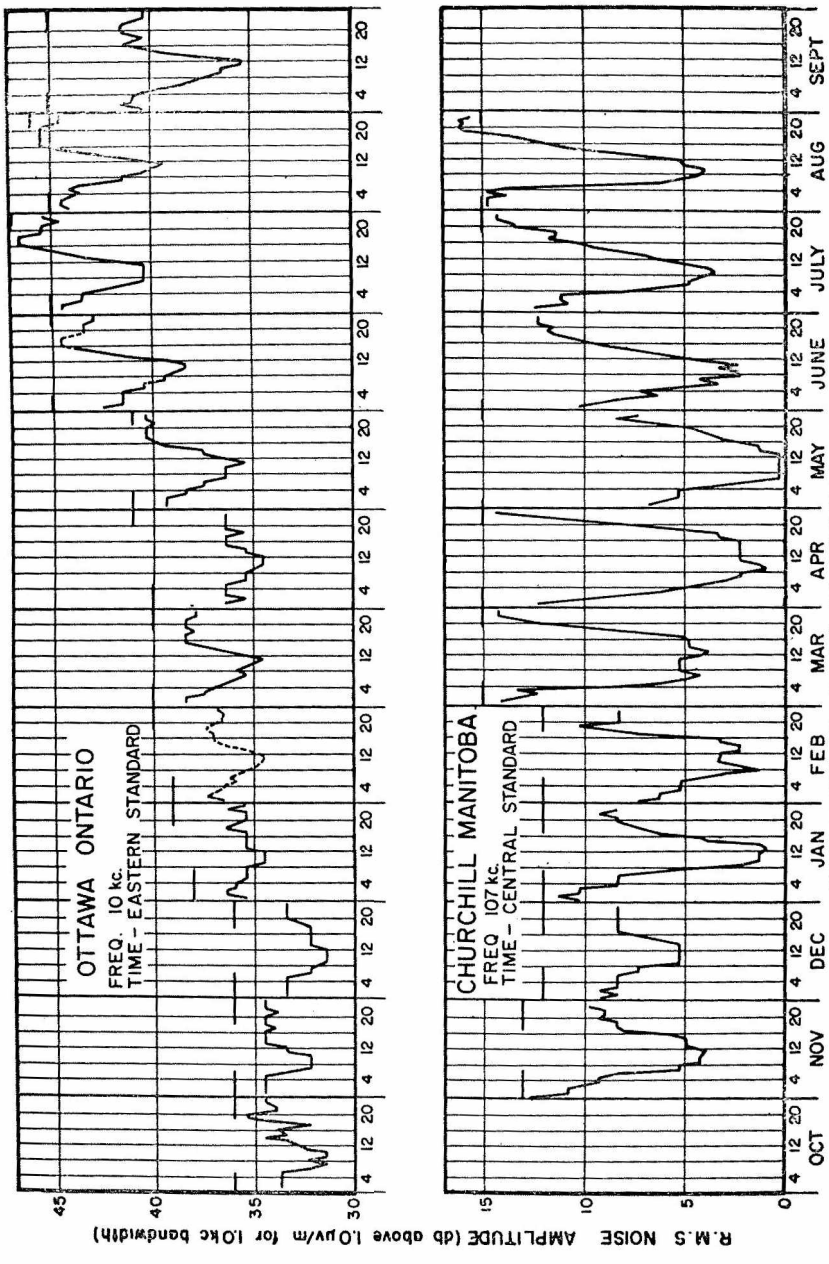


Fig. 5. — R. M. S. Atmospheric Noise

Radio Research Station and in the United States at the University of Florida, the University of Oklahoma, and the National Bureau of Standards at Boulder, Colorado. These measurements have been made at a variety of frequencies and no details are available at this time.

G. — *Probability Distribution of Noise Envelope*

The short-time characteristics of atmospheric noise can be conveniently expressed in terms of the amplitude probability distribution of the instantaneous noise envelope voltage. Many experimenters have made measurements of this type during the past several years, and detailed results are available.

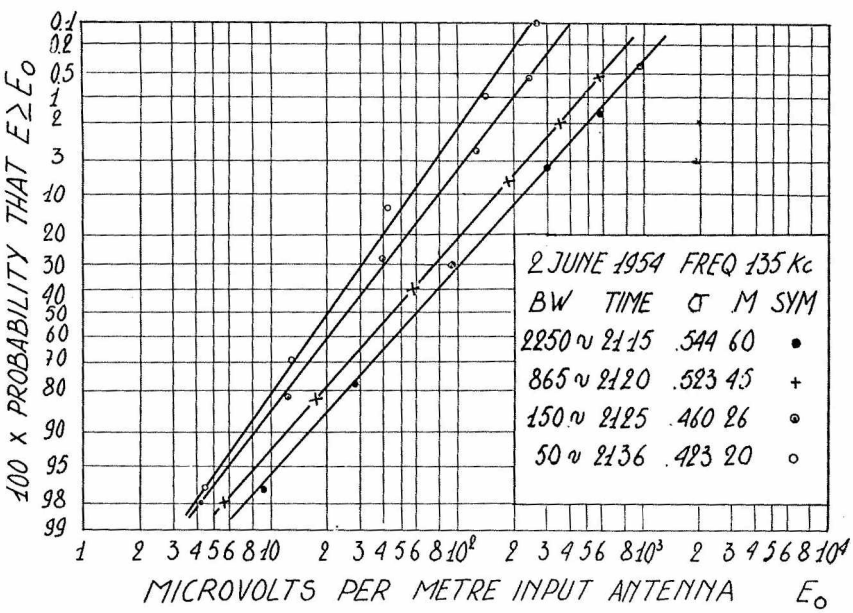


Fig. 6.

1. *University of Florida.* — Some of the earliest measurements of this type were made at the University of Florida, and typical results are shown in Fig. 6. The scales in this figure have been chosen so that a log normal distribution will plot as a straight line, and it can be seen that the data do fit the straight lines shown with reasonable accuracy. A log normal distribution has the advan-

tage that it can be expressed in terms of two simple parameters : the mean logarithm and the standard deviation, σ, expressed in logarithmic units. By simple mathematical relationships, it can also be expressed in terms of the average power and the average envelope voltage. Measurements made at the University of Florida have indicated that the log normal distribution does reasonably approximate the noise at this location.

2. *Telecommunications Research Laboratory (Union of South Africa).* — Amplitude probability distributions made in South Africa have been made by analyzing film recordings and also using equipment developed at the University of Florida which measures the percentage of time the noise envelope exceeds certain preset threshold levels. These results can also be approximated by means of a log normal distribution as shown in Fig. 7.

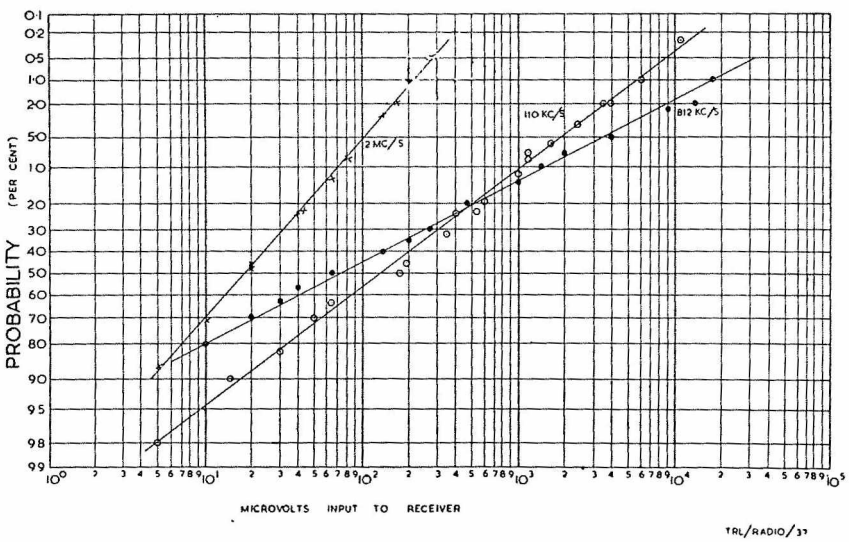


Fig. 7.

3. *France.* — Although no measurements of this type were reported from France, a discussion of the basis for a log normal distribution was submitted in which it was shown that this distribution can be derived from the product of a large number of independent variables.

4. *Radio Research Station (United Kingdom).* — Measurements in England have shown that the cumulative amplitude probability of the noise, that is the fraction of the time $Q(v)$ for which the envelope exceeds different voltages v, is given by

$$Q(v) = \left\{1 + \left(\frac{2v}{\bar{v}}\right)^q\right\}^{-1}$$

where Q is about 1.5 at 10 kc/s and somewhat greater at 25 kc/s. This formula is valid for values of $v/\bar{v}$ from 0.02 to 200, (values of $Q(v)$ from 10^{-4} to 0.99), and is substantially independent of bandwidth over the range 300 c/s to 1 kc/s. Typical results are shown in Fig. 8 (Horner and Harwood).

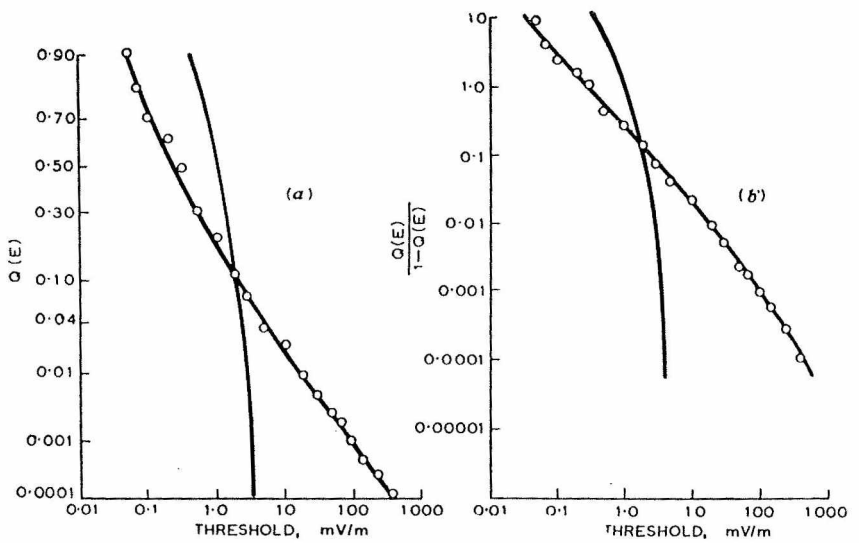


Fig. 8. — Cumulative amplitude probability distribution of atmospheric noise; 10 kc/s, 14th July, 1955.

—o—o—o— Atmospheric noise.

———— Fluctuation noise with same average field strength.

(*a*) Log-normal representation.
(*b*) Log-log representation.

5. *Radio Research Laboratory (Japan).* — The results of the probability distribution measurements at the Radio Research Laboratory are shown in Fig. 9. These distributions can be repre-

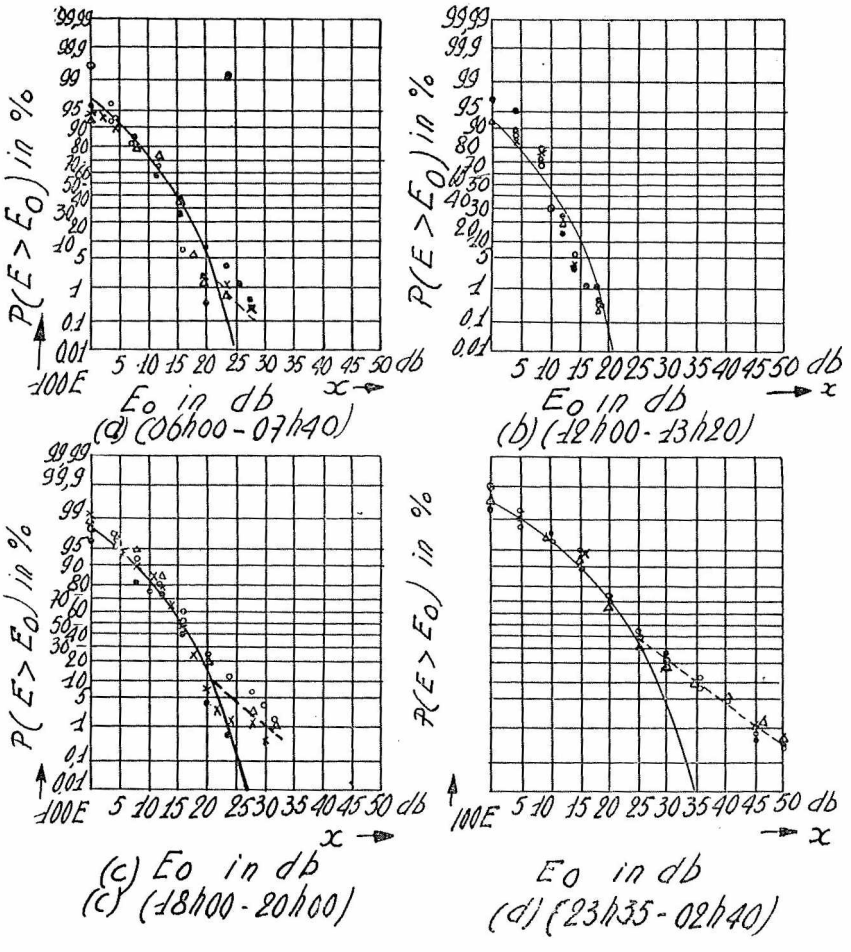


Fig. 9. — Example of A. P. D. of atmospheric noise at Ookira, July 30, 1955. Order of measurements :

——————— Rayleigh distribution.

●→×→△→○ log-normal distribution.

sented as a combination of a log-normal distribution of the high noise peaks and a Rayleigh distribution of the lower level overlapping pulses. This combination type of distribution has a somewhat firmer physical basis than the log normal distribution and is more easily explained from known characteristics of noise. However, being more complex it is difficult to express mathematically.

6. *Kokusai Densin Denwa Company (Japan).* — Probability measurements made by KDD are shown in Fig. 10. These measurements also show departures from the log normal distribution and are somewhat similar in shape to the distributions made by RRL.

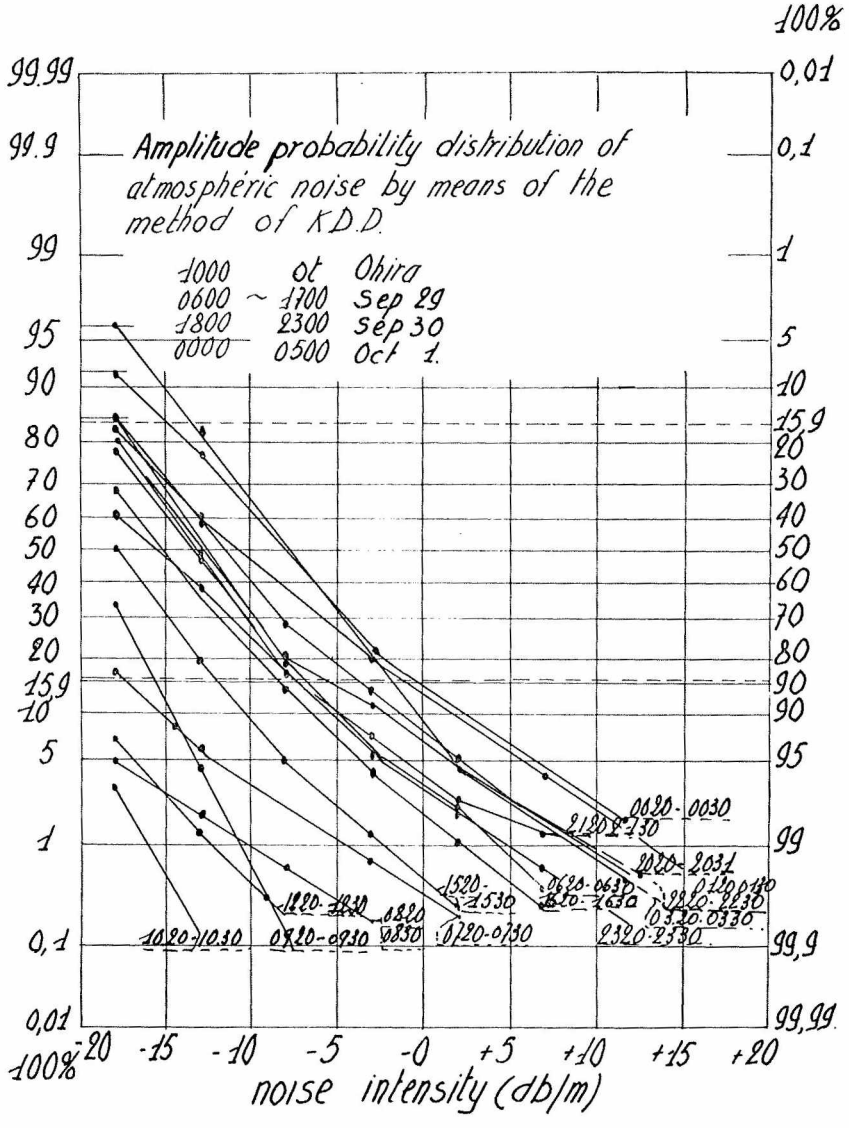


Fig. 10

7. *National Bureau of Standards (United States of America).* — Measurements of the amplitude probability distribution of atmospheric noise have been made by NBS over widely separated geographical locations at Alaska, Colorado, and Panama Canal Zone. Many of these distributions were plotted on logarithmic probability paper and in all cases significant departures from the log normal were observed. Figs. 11, 12, and 13 show typical

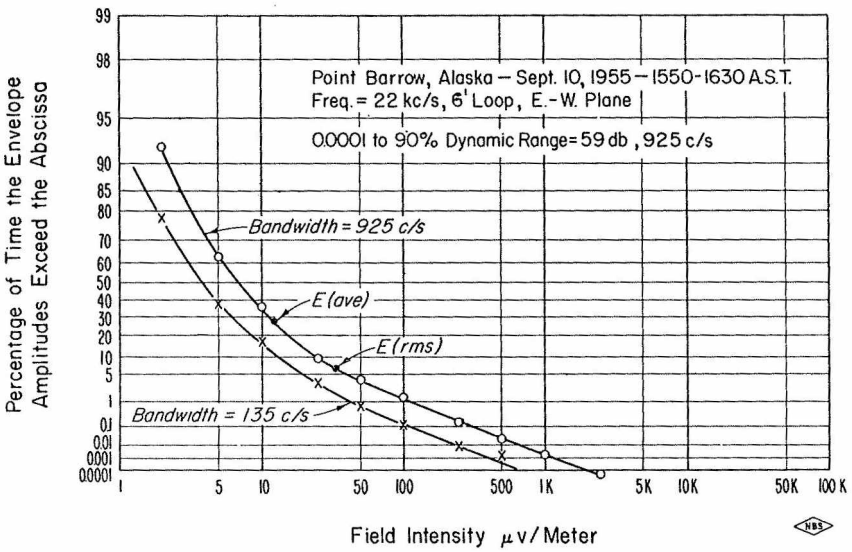


Fig. 11. — Amplitude distributions of atmospheric noise envelopes.

results from Alaska, Colorado, and Panama, respectively. The scales for these graphs have been chosen so that a Rayleigh distribution will plot as a straight line having a slope of —2. The low amplitude portion of all of these curves approaches asymptotically a Rayleigh distribution which would be expected from a large number of overlapping pulses. The high amplitude portion of these curves approaches another straight line at a different slope, and this portion of the distribution represents the high amplitude non-overlapping peaks in the noise. Figs. 14 and 15 show distributions measured in England and Florida that have been plotted in the same way as the NBS data. It can be seen that these distributions also have the same characteristic shapes.

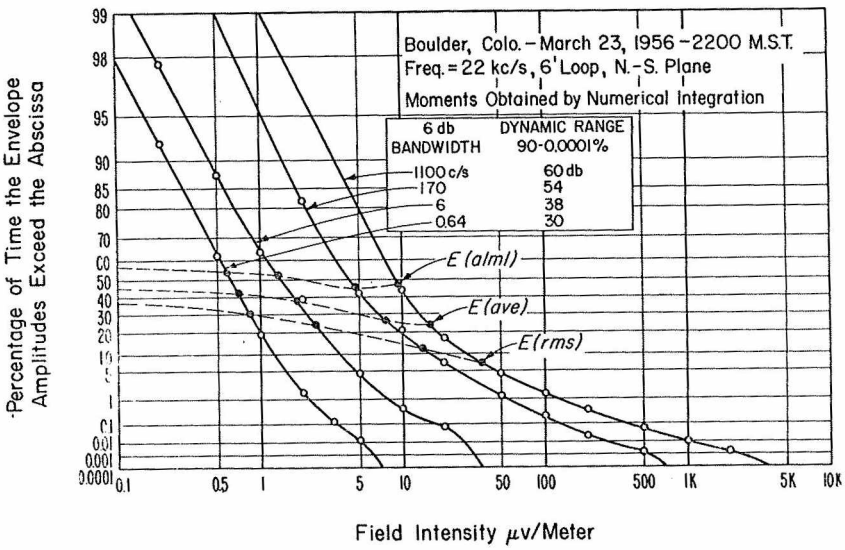


Fig. 12. — Amplitude distributions of atmospheric noise envelopes.

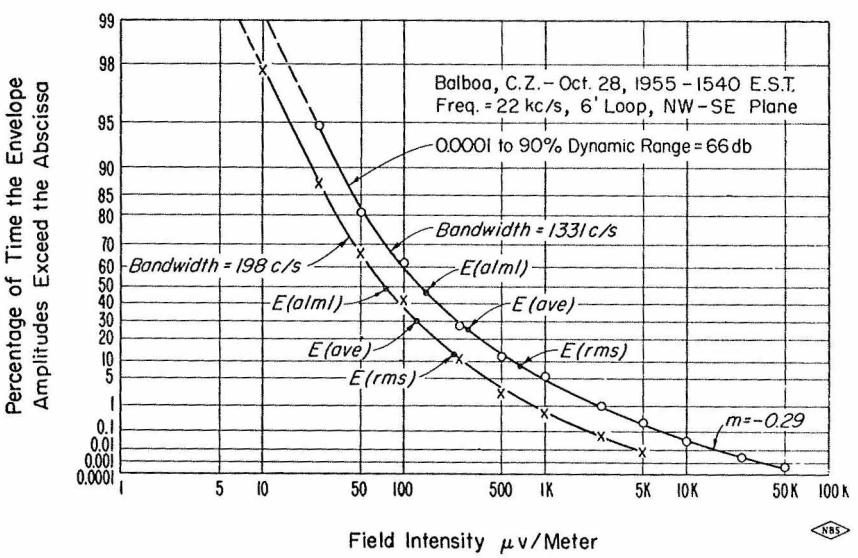


Fig. 13. — Amplitude distributions of atmospheric noise envelopes.

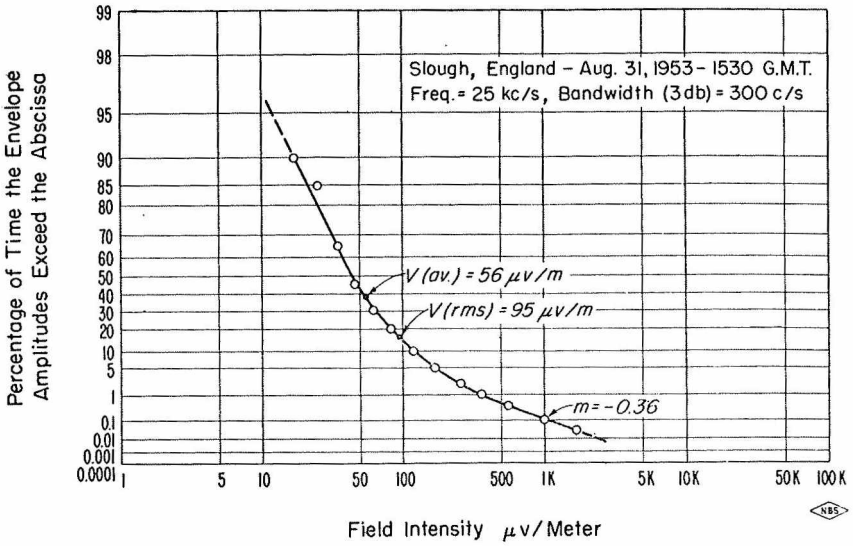


Fig. 14. — Amplitude distributions of atmospheric noise envelopes.

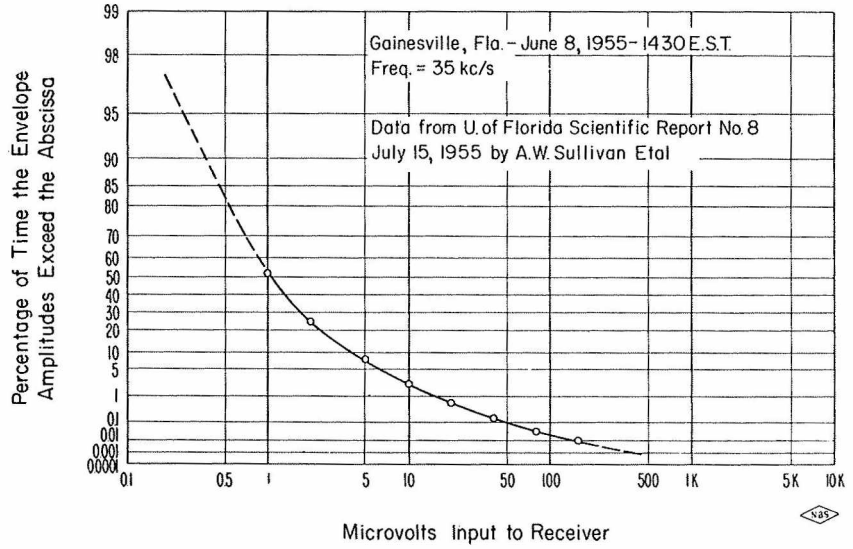


Fig. 15. — Amplitude distributions of atmospheric noise envelopes.

It has been found that the whole statistical distribution can be reconstructed from empirical relationships with measured values of the mean power, the mean envelope voltage, and the mean logarithm of the envelope voltage. Although these equations are more complex than those assuming a log normal distribution, much better approximations to measured data can be obtained by this process.

In addition to expressing the short-term characteristics by means of probability distributions, it is also convenient to express the long-term characteristics in a similar way. Fig. 16 shows a

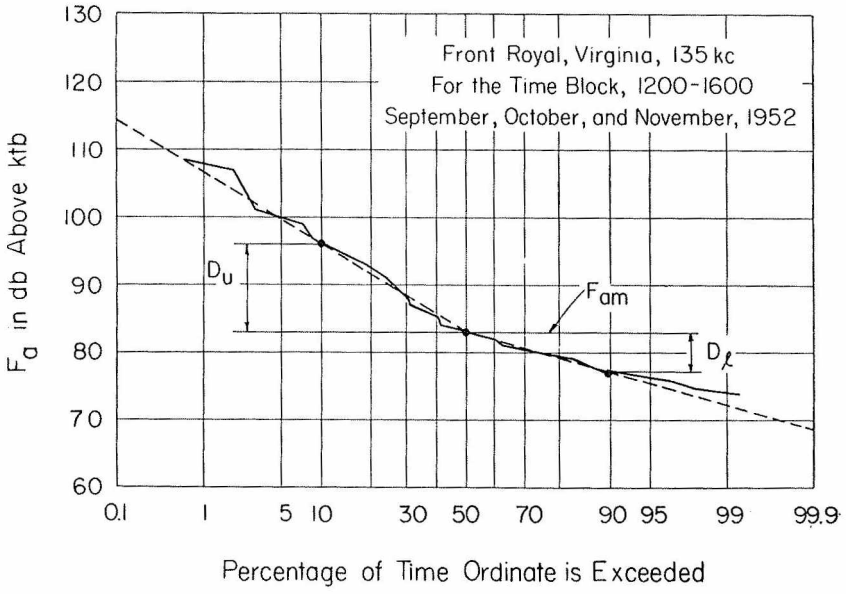


Fig. 16.

typical distribution of hourly medians measured by NBS for a four-hour period and during the Fall season. This distribution can be conveniently described by means of two straight lines, one of which passes through the upper decile and median and the other passing through the lower decile and the median. The whole distribution can thus be represented conveniently by these three parameters.

8. *Radio Regulatory Bureau (Japan).* — Amplitude probability distributions have also been obtained from measurements of the quasi-peak values by the RRB. Results of these measurements are shown in Fig. 17. Some of these distributions show resemblance to a log normal distribution, whereas others show marked departures.

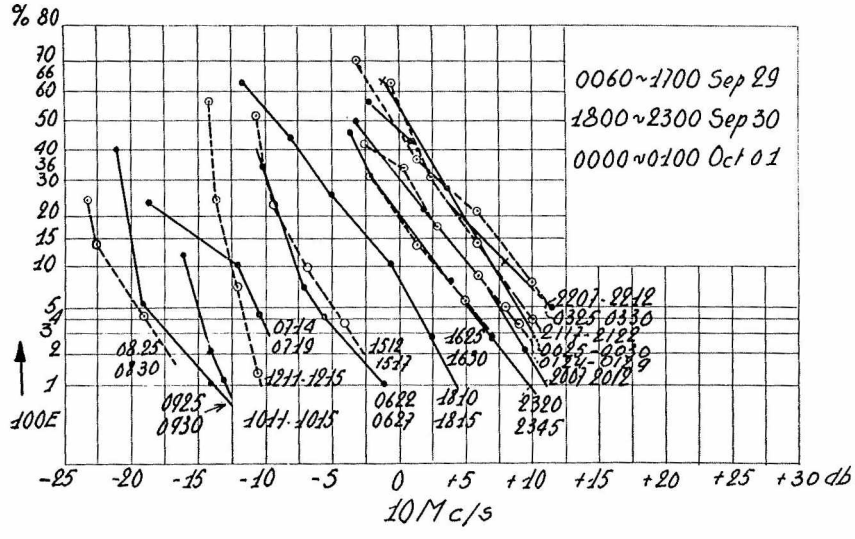


Fig. 17. — Distribution of quasi-peak atmospheric noise intensity measured by R. R. B.

H. — *Envelope Crossing Rates*

The measurement of the frequency with which the noise envelope crosses various predetermined levels provides additional useful information on the short-term characteristics of the noise. Measurements of this type have been made by the following organizations : Radio Research Station (UK), France, Radio Research Laboratory (Japan), University of Florida (U. S. A.), and NBS (U. S. A.). Typical results are shown in Fig. 18.

I. — *Ratio of R.M.S. to Average*

The relationship between the r.m.s. and the average is indicative of the character of the noise, and this relationship was investigated at several locations.

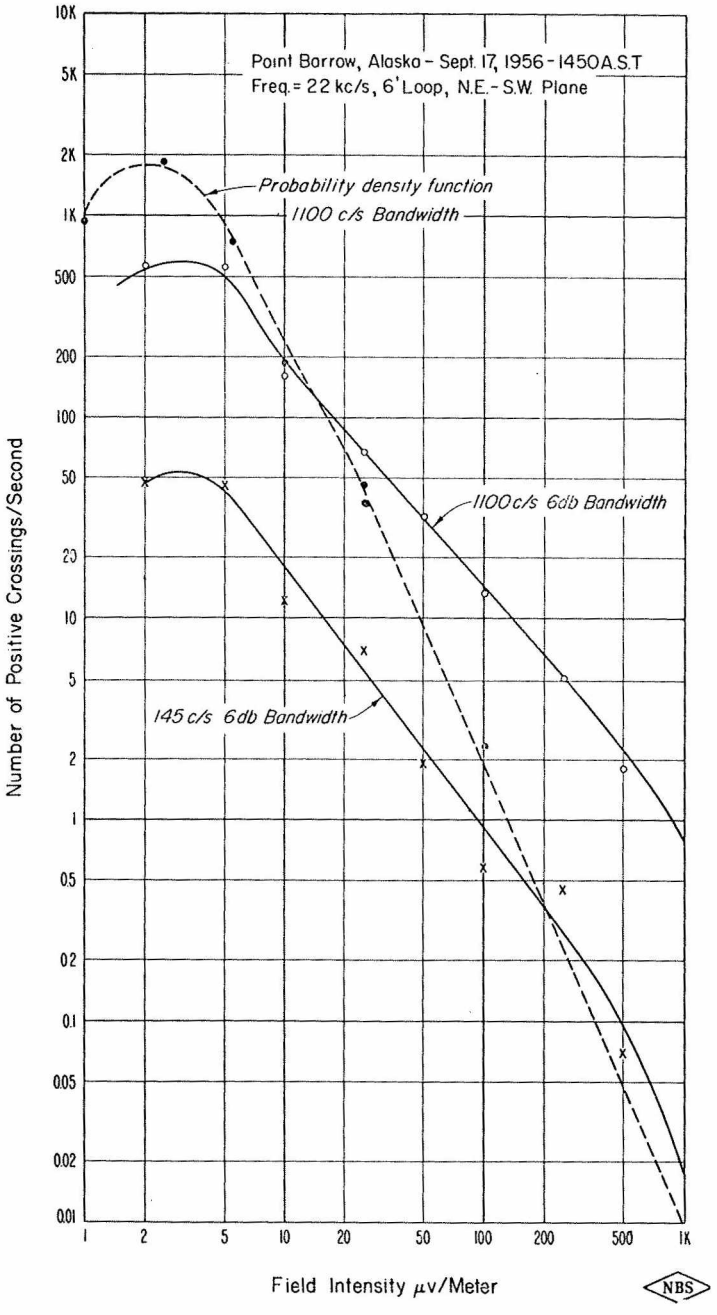


Fig. 18. — Crossing rate of noise envelopes.

1. *Telecommunications Research Laboratory (Union of South Africa).* — The ratio of the r.m.s. to the average was determined from photographic recordings of the wave form and also from probability distributions where the distribution was assumed to be log normal. The results are shown in the following tabulation.

TABLE III

Frequency	Ratios R.M.S. to Average	
	Waveform	Log-normal
100 kc/s	5.0	13.0
500 kc/s	2.60	2.40
8 Mc/s	1.45	1.38

2. *Radio Research Station (England).* — Measurements in England have indicated that the ratio of the r.m.s. value of the envelope to its average value varies between 4 and 8 in a bandwidth of 300 c/s at 10 kc/s with a mean value of about 6. The mean value at 30 kc/s is about 4 with similar variations. There is some evidence of a systematic diurnal variation in this ratio, but the evidence is not yet conclusive.

3. *University of Florida (U. S. A.).* — Calculations at the University of Florida based on a log normal distribution show that the ratio of the r.m.s. voltage to the average voltage is equal to exp $2.65\sigma^2$ where σ is the slope of the distribution expressed in logarithmic units.

4. *National Bureau of Standards (United States of America).* — Continuous recordings of the ratio of the r.m.s. to the average and also the r.m.s. to the average logarithm have been made at Boulder, Colorado over the frequency range 50 kc/s to 20 Mc/s during a period of about six months. Typical results are shown in Fig. 19 which is for nighttime hours during the spring season. The curve indicated as V_{dm} gives the median value of the average envelope voltage in db below the r.m.s. value. The curve indicated as L_{dm} gives the median value of the average logarithm of the envelope voltage expressed in db below the r.m.s. value.

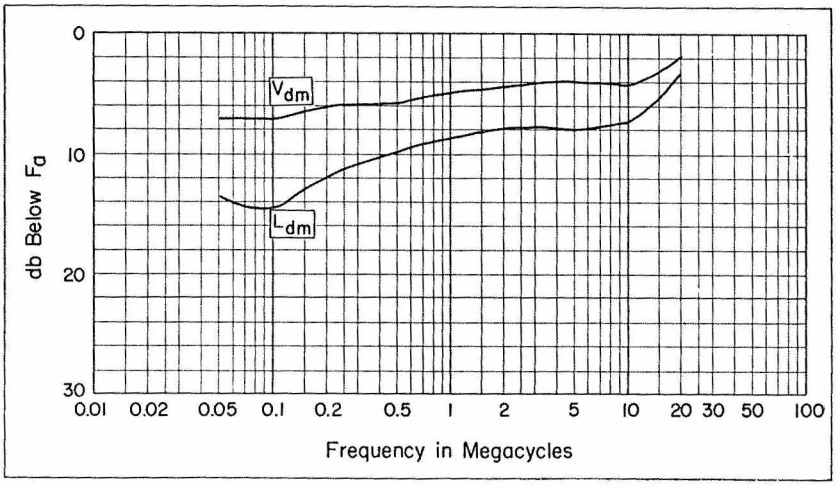


Fig. 19. — Median deviation for spring season;
time block 0000-0400 and 2000-2400, March, April, May, 1957;
Boulder, Colorado.

J. — *Effect of Bandwidth*

1. *Bell Telephone Laboratories* (*U. S. A.*). — The earliest published studies of bandwidth effect were made by Karl G. Jansky of BTL in the high-frequency band. These studies showed that both the r.m.s. value and the average envelope value were proportional to the square root of the bandwidth.

2. *Radio Research Station* (*UK*). — Measurements at RRS at VLF have indicated that the average envelope voltage is proportional to the square root of the bandwidth, if this is less than 300 c/s. For wider bandwidths, the relationship is between a cube root and a fourth root law. The r.m.s. voltage is proportional to the square root of the bandwidth.

3. *University of Florida* (*U. S. A.*). — Measurements at the University of Florida have indicated that the r.m.s. voltage is proportional to the 0.46 power of the bandwidth, and that the average envelope voltage is proportional to the 0.34 power of the bandwidth. Assuming a log normal distribution, the anti-log of the mean logarithm of the voltage was found to be proportional to the 0.18 power of the bandwidth.

4. *National Bureau of Standards (U. S. A.).* — The effect of bandwidth on noise distributions measured at Boulder, Colorado is shown in Fig. 12. The values of r.m.s. voltage, average voltage, and mean logarithm of the voltage were obtained by numerical integration of these distributions, and the variation of these parameters with bandwidth is shown in Fig. 20. Theoretical studies of the effect of bandwidth on the complete distribution of the noise have also been made at NBS, and methods have been developed for calculating the changes in shape and amplitude of the distribution from one bandwidth to another.

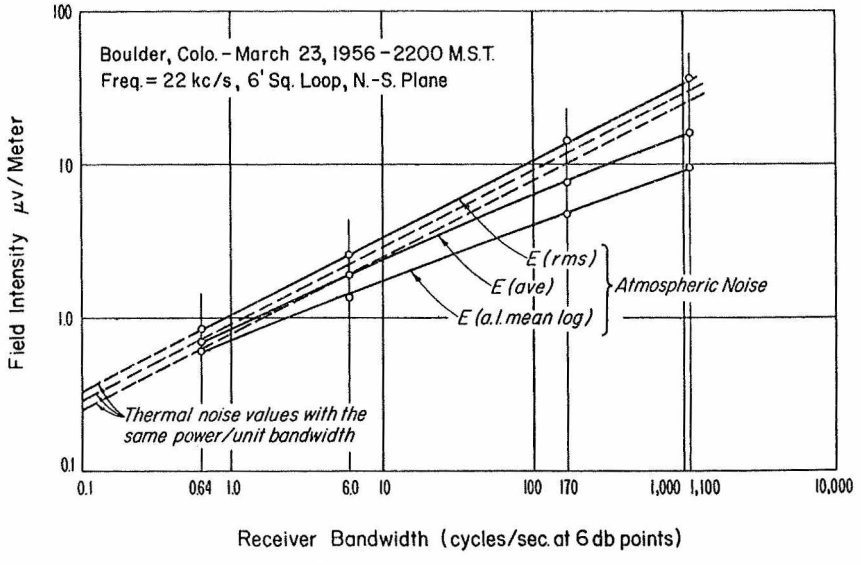


Fig. 20. — Atmospheric noise moments as a function of receiving bandwidth.

III. — Correlation between Measured Noise Parameters and the Performance of Communication Systems

Specific studies of the correlation between noise measurements and system performance were reported by only two agencies, the University of Florida and the National Bureau of Standards. However, it appears that significant results were obtained at both of these laboratories.

1. *The University of Florida.* — Table I contains the results of tests made with a manual CW radio-telegraph system using a single operator. Tests of a frequency-shift, radio-teletype system also are included in the table which states the probable error in db of signal strength that resulted in estimating the signal level required for 95 % copy on the basis of the indicated measures of noise.

TABLE IV

System	Probable Error-db		
	M-σ	Ave.	RMS
Radiotelegraph	$\pm$1.24	$\pm$1.58	$\pm$ 1.98
Radioteletype	$\pm$2.18	$\pm$2.89	$\pm$10.25

The db error is actually expressed as follows :

$$\text{Error-db} = 20 \log \left[\frac{\text{Signal level estimated from noise measurement}}{\text{Signal level required for stated reliability}} \right]$$

The probable error is, then, the root-mean-square of the errors obtained from many tests of system performance. The parameters of the noise given in the table were determined in all cases from the best fit log normal distribution.

Additional tests were made using single channel and multiplex frequency-shift, radio-teletype systems. In these tests, the percentage of errors was determined as a function of a signal level in the presence of atmospheric noise, and these error curves were compared with the noise distributions existing at the time of the tests. Typical results obtained with the multiplex system are shown in Fig. 21, where the error distribution has the same value of σ but is displaced in amplitude relative to the noise distribution.

Theoretical studies of the expected error distribution have been made at the University of Florida. Based on previous studies with a binary frequency modulation system, it was deduced that the signal error distribution should be equal to the noise probability

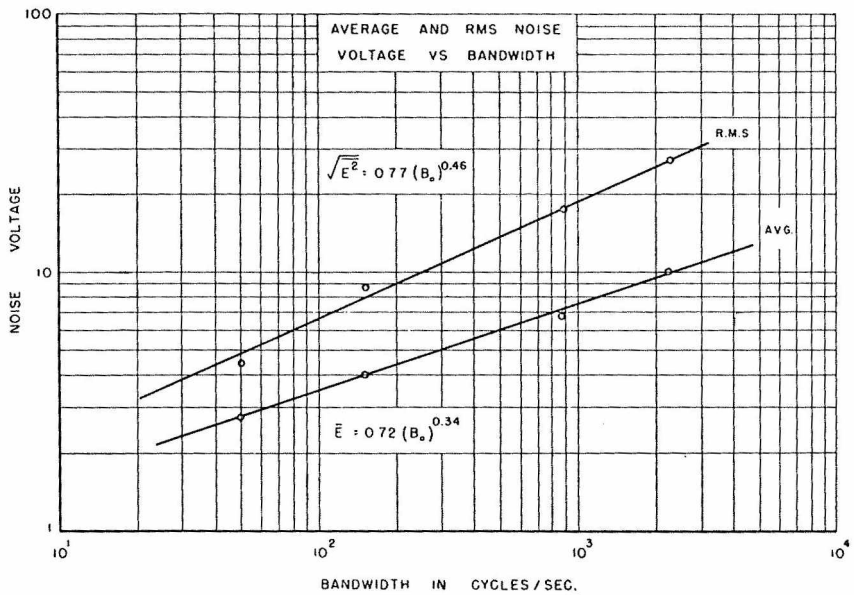


Fig. 21.

distribution. Experimental measurements have shown, however, that although the two curves are parallel the signal curve is equal to 3.51 times the noise curve at all percentage points.

2. *National Bureau of Standards.* — At NBS the performance of three frequently used types of radio systems — aural Morse code, frequency-shift keying teletype, and voice — has been examined under various combinations of typical carrier and noise conditions. In addition, the transmission rate and modulating conditions have been varied over the ranges typically encountered. Typical results of a teletype system operating in the presence of thermal noise are shown in Fig. 22. Based on the known behavior of a narrow-band binary system, the calculated error curve for a teletype system is compared with experimental measurements, and in the figure, it can be seen that the errors are the order of 1 db. The discrepancy of approximately 1 db is considered to be well within the expected accuracy. Fig. 23 shows a similar comparison of calculated and experimentally determined errors for a teletype system operating in the presence of atmospheric radio noise. In this case, even closer agreement was obtained between the calculated and experimental values.

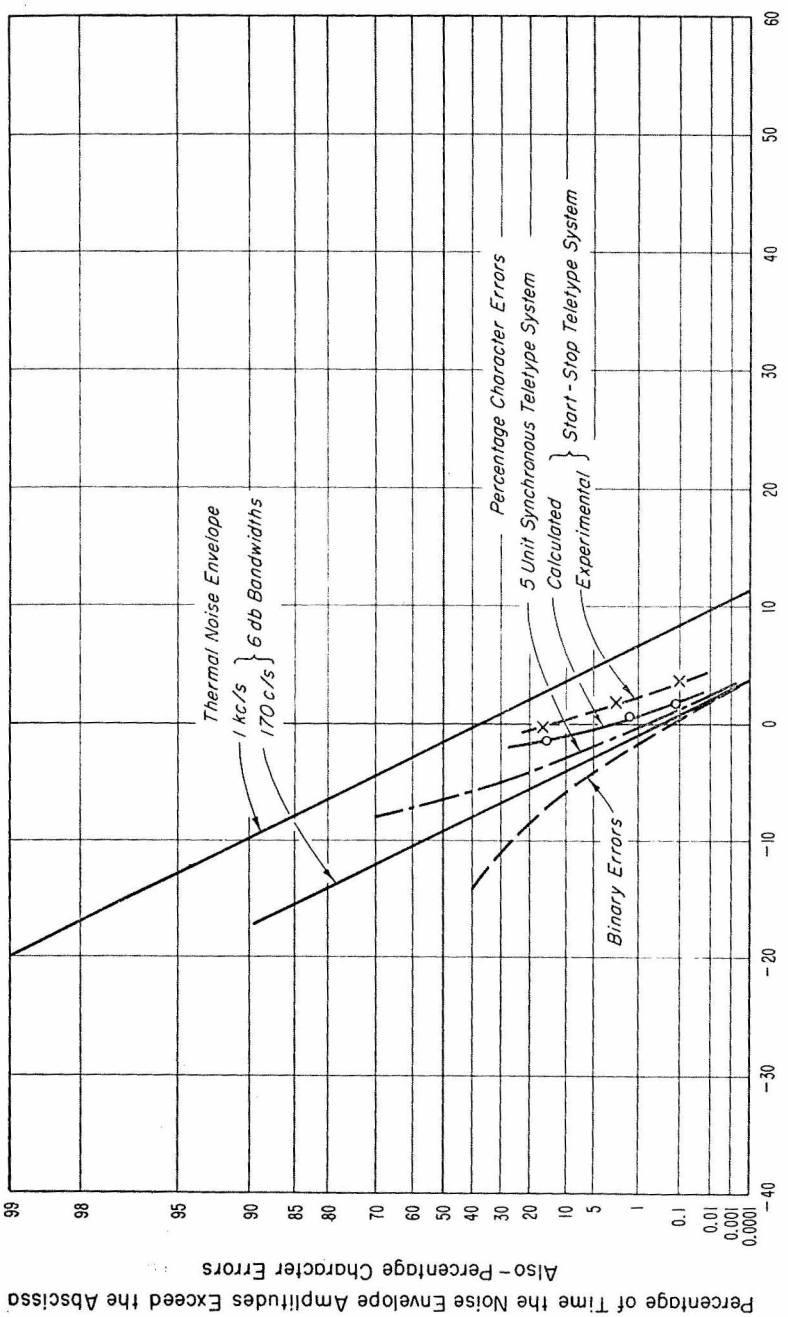


Fig. 22. — Communication system performance in the presence of thermal noise.

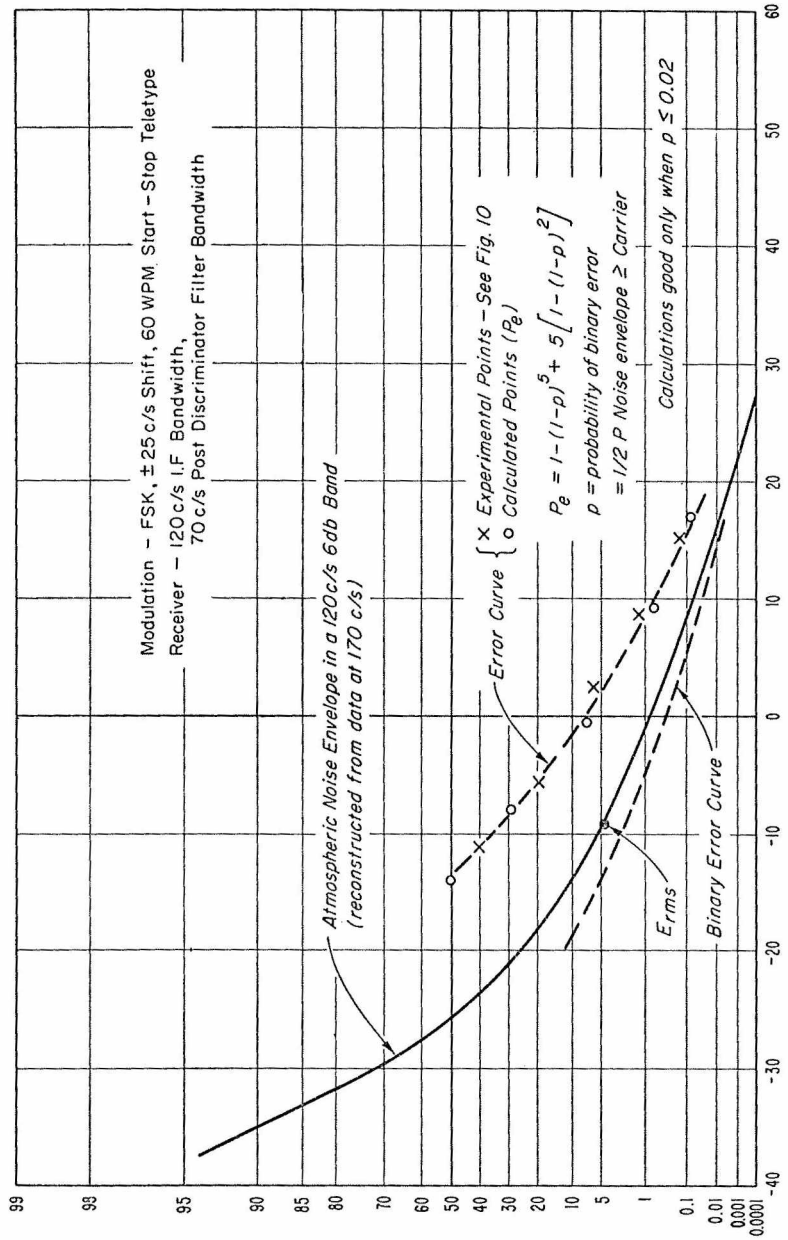


Fig. 23. — Comparison of calculated and experimentally determined errors.

IV. — Prediction of Levels and Characteristics of Noise

The purpose of making any noise measurement is to predict or forecast future noise characteristics or the behavior of future signals in the presence of noise. Therefore, before deciding upon which characteristic of the noise to measure, it is desirable to see how this measurement of the noise would be used in a prediction.

The most recent predictions of world-wide radio noise were published by the C.C.I.R. at the VIIIth Plenary Assembly in Warsaw, 1956, as Report No. 65. The basic parameter used in these predictions is an effective antenna noise figure, F_a, which has been defined as the noise power available from an equivalent lossless antenna in db above kTB (the termal noise power available from the passive resistance of a circuit with bandwidth B and at the absolute temperature T). F_a in db is simply related to the r.m.s. field strength at the antenna by the following equation :

$$E_n = F_a - 65.5 + 20 \log_{10} F_{mc}$$

where

E_n = the r.m.s. field strength for a 1 kc/s bandwidth in db above 1 μV/m.

F_{mc} = the frequency in Mc/s.

The value that is predicted is the median value of F_a during a given four-hour period and season. Fig. 24 is a typical chart from the C.C.I.R. predictions and shows noise-grade contours for the period of time, June-July-August, and for nighttime hours, local time. This chart illustrates the geographic distribution of the noise, and as the storms progress from the northern hemispheric to the southern with seasons, the noise level as received at any particular location will, therefore, show a systematic seasonal variation. Similar charts have been prepared which show the systematic variation of the noise contours with time of day and twenty such charts cover both the diurnal and seasonal variations.

Fig. 25 is also taken from the C.C.I.R. predictions, and illustrates the systematic variation of noise level with frequency. Having determined a noise grade at a particular location from a chart similar to Fig. 24, it is then possible by use of these curves to determine the expected noise level at any other frequency. This

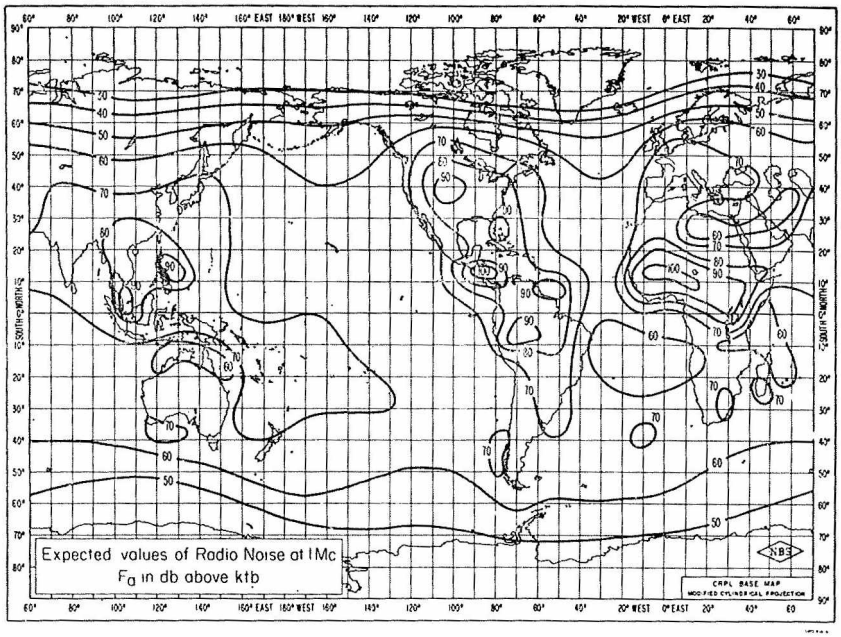


Fig. 24. — Noise distribution chart
for the period June-July-August, 0000 to 0400 and 2000 to 2400.

particular graph is for nighttime propagation conditions, and a similar set of curves has been provided to show the frequency variation during daytime propagation conditions.

The hourly values for a given time block vary from hour to hour and day to day in an unpredictable manner. The extent of these variations is shown in Fig. 26 on which are plotted the ratios in db of the upper decile to the median values, D_u, and of the median to the lower decile values, D_l. These ratios depend on a number of parameters, but the frequency has been found to be the most significant. D_u has its highest values at sunrise and sunset owing to the change from daytime to nighttime propagation conditions, and also during the afternoons owing to the presence of local storms.

Although these previous predictions have been concerned with the level of the noise only, it is highly desirable for future predictions to provide means of estimating the characteristics of the noise as well.

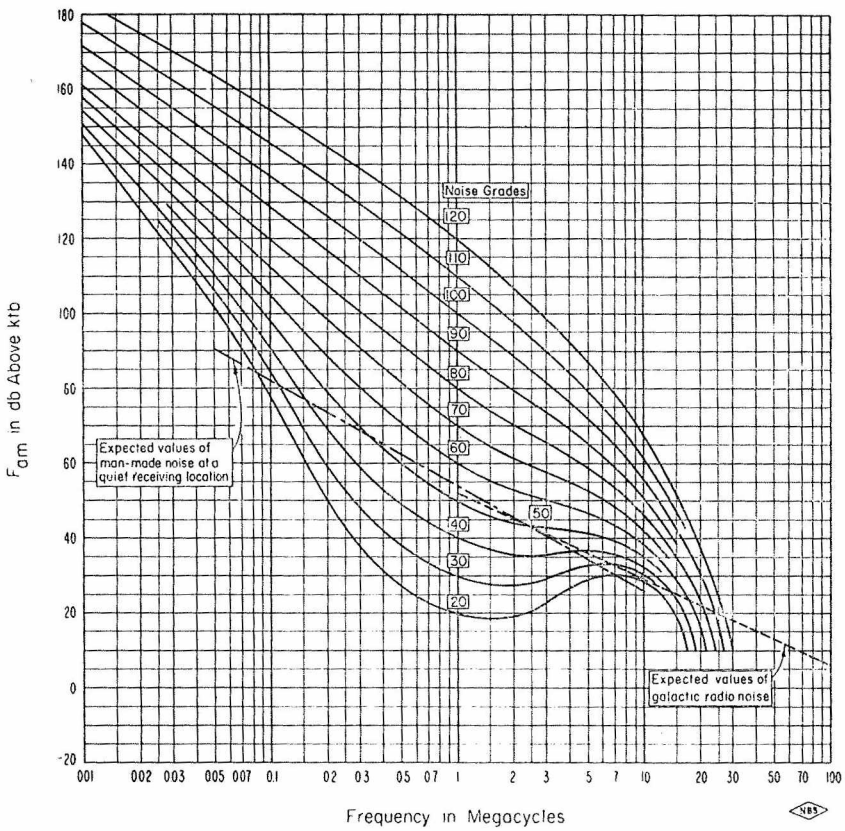


Fig. 25. — Time block median values of radio noise expected for a short vertical antenna, for the time blocks 0000-0400 and 2000-2400 (all seasons), and 0400-0800 and 1600-2000 (fall and winter).

V. — Recommended Measurements

The subcommittee as a whole indicated that it would be highly desirable to obtain information on the amplitude probability distribution of the instantaneous noise envelope voltage at as many locations throughout the world as was practicable. However, since continuous measurements of the complete distribution at all frequencies at a large number of stations becomes prohibitive because of the complexity of the equipment involved and the large number of personnel necessary to carry out the observations, it has been suggested that these complete studies of the detailed

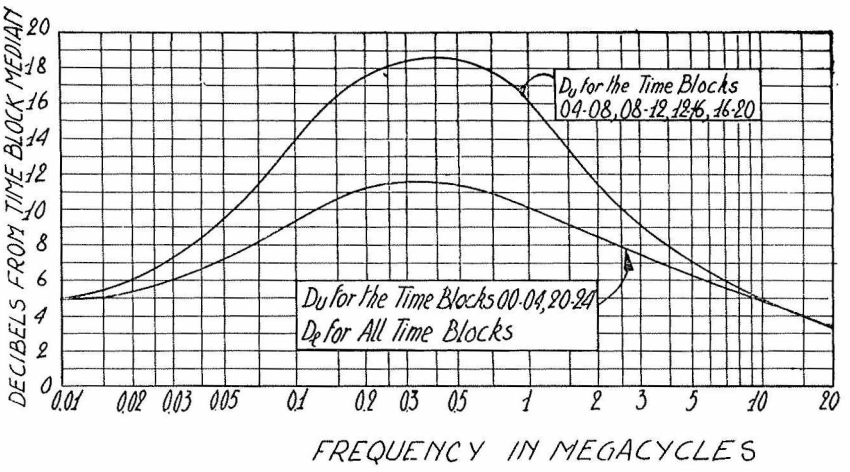


Fig. 26. — Variations from the time block median radio noise levels.
D_u = Ratio of Upper Decile to Median in Decibels.
D_l = Ratio of Median to Lower Decile in Decibels.

noise characteristics be confined to a few selected locations with continuous measurements of one or more simple parameters made at a larger number of stations.

If it should be shown that the assumption of a log normal distribution gives an adequate description of the characteristics of the noise at all times, places, and frequencies, then only two parameters would be necessary to define the existing log normal distribution. These measurements could be the average power, the average voltage, the average logarithm, the value exceeded for particular percentages of the time, etc. Appropriate pairs of these parameters could then be chosen to describe the complete distribution.

If a more complex description of the distribution is necessary, then additional moment measurements would be needed to describe the distribution. For example, using a distribution of the form in use at NBS, three moments are required to adequately describe the distribution.

The number of moments actually necessary to describe the true distribution will be determined by the variability of shape that is observed from one place to another and as a function of time and frequency. If a sufficient number of systematic tendencies can

be found for the shape of the distribution, then fewer moments will be required to show the variability.

The actual moments that are selected for measurement depend upon, for one thing, the portion of the distribution that is of the greatest interest. For example, the r.m.s. value or the average power is determined largely by the high amplitude values of the distribution, i. e. values exceeded 10 % of the time or less. The average logarithm is influenced by values in the distribution exceeded the order of 50 % of the time, and the average envelope voltage is influenced by values of the distribution in between these two parameters. The quasi peak, which has received some favor in the past, is influenced by values in the high amplitude portion of the distribution ; however, this type of measurement does not lend itself as well to mathematical analysis and is not as easily related to the actual measured probability distribution as other parameters.

The committee also found the rate of crossing of various amplitude levels to be a useful measure of the noise, also measurements of the time between pulses as well as distributions of pulse lengths at various amplitudes.

It is important to continue studies of the relationship between the various parameters such as the ratio of the r.m.s. to the average under all conditions, i. e. as a function of time, frequency, and location. Additional studies of the influence of bandwidth on all of the parameters are quite desirable.

In making any measurement of noise, it is extremely important to carefully state all conditions of measurement so that observations by different experimenters can be interrelated.

In summary, it was concluded by the group that first preference should be given to measurement of the complete amplitude probability distribution where practicable and to measure at a large number of locations the moments from which statistical distributions can be derived such as average, r.m.s., average logarithm, etc.

VI. — Specification of the Noise Meters

Detailed specifications for specific noise meters are beyond the scope of this report ; however, a brief discussion will be given of the general characteristics of equipment designed to make specific types of noise measurements.

A. — *Probability Distributions*

In making detailed statistical measurements on the instantaneous noise envelope voltage, it is recommended that measurement should be based on counting techniques. These are the most versatile, since counting equipment can readily be adapted to the measurement of a number of parameters. For example, the amplitude probability distributions and the distributions of the pulse lengths, and the intervals between the pulses.

The equipment necessary for making such measurements will generally contain the following components :

1. antenna.
2. calibrating signal.
3. calibrated attenuator.
4. receiver.
5. selective circuits of known or adjustable bandwidth.
6. envelope detector.
7. amplitude discriminator.
8. gating circuits.
9. signal generator (usually about 10 kc/s).
10. one or more frequency counters.

The design of the receiver must be such that its recovery time is very short upon overload by high amplitude pulses. Except for this limitation, there are no severe dynamic range or linearity requirements. The receiver noise, of course, must be lower than the level of external noise that is to be measured.

The distributions are obtained by gating the 10 kc/s signal on for the period of time during which the noise level exceeds the threshold of the gating circuits, and by changing the amount of the attenuation at the input of the receiver in known steps. Various lengths of counting time are used at the different threshold levels. In general, 100 seconds is used for values of 5 % and greater, 200 seconds for values in the range of 0.0005 to 5 %, and 300 to 1000 seconds for values less than 0.0005 %. In general, a total of about 10 minutes are required to obtain all but the last three low percentage ratings, which themselves may take 10 to 20 minutes in order to obtain statistically constant data. The total time required is a function of the type of noise being measured. A longer time is required for noise with a large dynamic range.

B. — *Individual Moments*

1. *The Average Envelope Voltage.* — The basic equipment for measuring the average envelope voltage is as follows :

(*a*) antenna.

(*b*) calibration source (signal generator or noise diode).

(*c*) receiver with controllable gain (AGC or variable attenuator).

(*d*) frequency selective circuits of known or adjustable bandwidth.

(*e*) envelope detector (detector capable of following the peaks of the I. F. cycles at the audio-frequency rate).

(*f*) integrating circuit (usually an RC circuit with a time constant of 100 seconds or more).

(*g*) AGC circuit (the integrated voltage should control the gain of the receiver so that the operating point of the detector is essentially constant for all levels of noise).

(*h*) recorder circuit (the recorder should indicate the magnitude of the AGC voltage which is calibrated in terms of the input signal level).

It is essential for the receiver to be linear over the important dynamic range of the noise being observed for a fixed value of AGC voltage, so that the noise envelope is undistorted at the detector output. This requires an instantaneous dynamic range of the order of 40 db or more. The required dynamic range is a function of the type of noise being measured and the bandwidth of the equipment. The narrower the bandwidth, the smaller the dynamic range. Usually bandwidths the order of 300 cycles to 1000 cycles are used. The gain stability of the equipment must be adequate to insure repeatability of calibrations. The noise figure of the equipment must be low enough to insure uncontaminated reception of the lowest noise levels.

2. *R.M.S. Voltage.* — The required circuitry required for measuring the r.m.s. voltage, or average noise power, is similar to that required for average enveloppe measurements, except that just prior to detection a square law circuit is used. This circuit can consist of two tubes with the grids in push-pull and the plates in parallel ; thus, producing in the plate circuit a voltage at twice the input frequency and with an amplitude proportional to the

square of the input voltage. The amplifier and detector that follow must have a much larger dynamic range in order to handle the squared values without distortion. Using a bandwidth of about 300 c/s, a dynamic range of 80 db or more is required ; however, much smaller bandwidths can be used for the power measurement, since the power is directly proportional to bandwidth regardless of the type of noise. Using a bandwidth the order of 1 c/s, the required dynamic range is reduced to about 40 db or less, since for these bandwidths the noise has the characteristics of thermal noise and approaches a Rayleigh distribution. The time constant used will depend to a certain extent on the bandwidth ; however, a time constant of 500 sec seems to give adequate smoothing.

3. *Mean Logarithm.* — The equipment required for measuring the mean logarithm is again very similar to the equipment for average envelope measurements. The principal difference is that a logarithmic amplifier is inserted between the envelope detector and the integrating circuit. A convenient circuit is a triode operating at zero bias and with a high value of grid resistance so that the plate current is an exponential function of the applied grid voltage. With this type of measurement, a time constant of the order of 50 seconds has proven satisfactory. It should be noted that the logarithmic amplifier must be capable of operating at the envelope frequency, i. e. the integration must occur after the logarithmic circuit rather than prior to or within the logarithmic circuit. It should also be noted that the AGC voltage must be obtained after integration rather than before integration.

VII. — Data Processing and Presentation

A. — *Data from Moment Measurements*

It is recommended that data obtained from measurements of the moment such as r.m.s., average, etc. be processed in very much the same manner as in the past, such as is used in the presentation of noise data in the CRPL-F series, an NBS publication. Since all of the moments are obtained in the form of averages over a minute or more, the median value of this average should be obtained for a period of one hour. In lieu of continuous recordings,

a suitable sample should be made during each hour. The basic unit is then the hourly value. Approximately thirty such hourly values are then available during each month. The distribution of these hourly values can be represented by means of the median, and the upper and lower decile values. The diurnal variation of the moments can then be represented by plotting the monthly median for each hour of the day, and the variation about the monthly median is then represented by the upper and lower decile values. It is sometimes convenient to group the hourly values in time blocks of four hours during a three-month season, and to obtain the corresponding time-block medians and decile values. These units of time were used in the C.C.I.R. noise prediction Report No. 65.

B. — *Statistical Data*

When sufficient statistical data have been collected to firmly establish typical shapes of the amplitude probability distribution so that these distributions can be adequately represented in terms of one or more statistical moments, it would be desirable to publish typical distributions in families of curves. These curves could all be normalized to one of the moments, such as the mean power, and grouped in accordance with gradual variations of the other moments such as the average voltage and average logarithm. Using predicted values of the moments for a particular time, place, and frequency and bandwidth, it would then be possible to use the appropriate curve representing the complete statistical distribution that would be expected for the predicted moments. In order to establish such a set of typical probability distribution curves, it is highly desirable for each experimenter measuring complete distributions to determine by numerical integration or other means the corresponding moments, so that these relationships can be established.

C. — *Future Predictions*

The noise predictions that have been previously published actually consist of the best estimate of noise conditions that have existed in the past, and it has been assumed that noise levels will repeat themselves from one year to the next. Ideally, a prediction should consist of the best estimate to be expected for a particular

date and time in the future based on expected meteorological conditions as well as propagation conditions. The prediction becomes very complex under these circumstances and considerable expansion of our experimentation will be necessary before such a detailed prediction will be possible. The extensive program of geophysical measurement being undertaken during the International Geophysical Year, should yield important information on the relationship of all factors influencing the received noise level and characteristics. Thus, by proper utilization of this vast amount of information becoming available to us, it is anticipated that much improved prediction methods will be possible in the future.

Subcommittee Membership :

F. J. HEWITT, Union of South Africa.
F. HORNER, United Kingdom.
G. FOLDES, France.
H. SHINKAWA, Japan.
A. W. SULLIVAN, United States of America.
W. Q. CRICHLOW, United States of America.

Collaboration with the C. C. I. R.

The Plenary Assembly of the C.C.I.R. held in Warsaw in 1956 asked for the collaboration of U.R.S.I. to deal with Study Programme n° 96 (VI) (Measurement of atmospheric radio noise) which interests the activities of Commission IV.

This study programme was published in *Information Bulletin*, n° 100 (November-December, 1956).

National Committee Reports

Australia

N° 224. — Report of the National Committee to Commission IV

The noise survey using the Thomas system has continued at Pearce (West Australia) for 3 years, Rockbank (Victoria) for two years, and Darwin (Northern Territory) for one year on the five frequencies 2.5, 5, 10, 15 and 20 Mc/s. The recorders are being modified to cover other frequencies of 0.5 and 1.5 Mc/s and recording included three frequencies at Pearce from August 1955 and at Darwin since February 1956.

Arrangements have been made for the analysis of this data and this is completed to about the middle of 1956. It is proposed to transfer the Rockbank station to Cloncurry (Queensland). The Pearce recorder is also to be moved to a location yet to be selected.

Noise measurements at 11.5 Mc/s have also been made on directional aerials at Rockbank for comparison with the Thomas equipment records. Arrangements are in hand to install an N.B.S. recorder.

Installation of one or two Cathode Ray Direction-Finders for study of thunderstorm atmospherics is also planned.

France

N° 211. — Report of the National Committee to Commission IV

(*Translation*)

1. — Whistlers

Whistlers are observed in Poitiers (geomagnetic latitude 40°) from 1955 on 1 to 10 kc/s (1). This survey is made almost continuously by aural monitoring or hourly records on magnetic tape.

Whistler activity has a minimum between July and October and a maximum between November and March, owing to thunderstorm activity at the geomagnetically conjugate point in the southern hemisphere. The correlation between whistler occurrences and sources of atmospherics is verified on the basis of meteorological data and by direct observation of sources of atmospherics at the south of Crozet and Marion Islands from the Kerguelen. Short whistlers appeared in fact more often ; long whistlers were rarely observed in 1955 and 1956 and are more frequent in 1957.

Whistler detection at noon or more than 24 hours consecutively is exceptional. Whatever their type, they are observed at the end of the afternoon and they disappear between 05.00 and 06.00 UT. A minimum of whistler activity is in every case observed about one hour after sunset at ground. This receiving period is also coincident with a period of eventual pulsed atmospherics followed by multiple echoes (type 4). Moreover, when long whistlers preceded by an atmospheric are detected, this atmospheric is always of type 4. The D-region plays then an important role in whistler propagation : it seems that this region constitutes the birthplace of whistler phenomena and that multiple reflections on the ionosphere are a stage of their formation (2).

Observed whistlers are analysed by several discriminators between 2 and 8 kc/s and by oscillographic recordings. Their dispersions do not vary much during several hours, and few with the season. They amount to about 65-70 $sec^{\frac{1}{2}}$ for short whistlers, and to about the double for the long ones. The more dispersed echoes that may follow them are generally very weak. However, several day-lasting periods have been observed where attenuation is weak from one echo to the following ; many whistlers may be detected during these periods, and these whistlers are finally clustering themselves in a noisy sound of almost constant frequency.

The maximum of amplitude occurs between 3.5 and 4.5 kc/s. Oscillographic records have shown that pure whistlers have a sinusoidal waveform ; the fuzzy impression they most often give in a loudspeaker is due to a superposition of several pure whistlers of equal dispersions, delayed some tens of milliseconds and interfering.

At the first moment after sunrise, other kinds of whistlers con-

nected with dawn chorus are sometimes received. They are weak and short (from 4 to 10 kc/s in 0.1 sec) and proceed with an increasing frequency, or with a frequency decreasing first and then increasing with time. They are often associated with a more or less continuous noise. Their occurrence is in close connection with magnetic or ionospheric disturbances or with auroral activity.

Since 1955, observations are also made at Kerguelen Islands (geom. lat. —57°). At this location, the seasonal variations of whistler occurrences is the inverse of that observed in Poitiers, and short whistlers are predominant. During active periods, they are received during the whole day with a maximum beginning one hour after sunset and extending to 01.00, and a minimum from 10.00 to 15.00 local time. No correlation in time has been observed between Poitiers and Kerguelen observations, except for short whistlers with increasing frequencies that, in Kerguelen, follow the magnetic disturbances with a time delay increasing with the strength of this disturbance, and amounting from one to five hours. The reception of these whistlers show only a few background noise.

In addition, measurements of the direction of arrival and of the polarization of whistlers have been made on 5.5 kc/s (3). These directions are located in two cones whose axis correspond to the Earth's magnetic field direction and whose half-angles at the apex are approximately 5° and 25°, respectively. This confirms Storey's theory. On the contrary, the electronic density at high altitude deduced from polarization measurements, appears 10 times lower than the value proposed by Storey.

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II. — Relationships between atmospherics and thunderstorm activity

Routine records of rates of occurrences and average fieldstrength of atmospherics (1) have been made at the « Laboratoire National

de Radioélectricité » on wavelengths from 60 m to 130 km. The equipment for I.G.Y.-observations has been built ; mechanical recorders have been abandoned and replaced by recording milliammeters. High resolution direction finding, which is operated permanently on 11 km wave-length, has been tried on 57 km and 5 km. The existing experimental network has been developed ; rate meters and average fieldstrength recorders have been placed in Bangui (AEF), Tahiti and Iva (Madagascar), and a high resolution direction finder in Bangui.

MM. Bureau, Bost and Bertrand (2, 3, 4) have determined the relationships between some typical thunderstorms and corresponding records of rates and average fieldstrengths. R. Bost (5) has shown the possibility of making short time forecastings of the thunderstorm processus with a high resolution direction finder. He has also evidenced the interest of observations on 60 m in the detection of 30 to 60 km distant thunderstorms.

The results obtained with cathode ray direction finders and average fieldstrength recorders on 11 km wave-length during the 1949-1950 campaign of the ship « Commandant Charcot » on the path France — Terre Adélie — France have been published by M. Barre (6) ; the same author presented the results for the expedition of 1951 in Terre Adélie (7). J. Le Gall published the results for the expedition of 1951 at Kerguelen Islands (8, 9).

Broadly, these results are in good agreement with Brook's charts for continental atmospherics. As well in Terre Adélie as in Kerguelen Islands, the nocturnal maximum of the mean level occurs before mid-night, indicating the preminency of western sources ; this explanation has however not been retained by Bost (9).

The « crevices », sudden falls of mean level which are sometimes observed during the night, are connected with the existence of an auroral E_s-region detectable by local ionospheric soundings. They are coincident with the appearance of a magnetic depression on the magnetograms.

The authors described the characteristics and the evolution of African thunderstorms foci and those of Malgache Islands, Eastern India, Sunda Islands, Australian Southwest, Pacific Islands where activity due to Fidji and Samoa is greater than activity due to New Zealand. From Kerguelen Islands, atmospherics coming

from dynamical oceanic foci, which are active in the neighborhood of Crozet Island, are also received. No atmospherics are received from Antarctica. These results show that, on 11 km wavelength, atmospherics may be detected which come from sites distant of 10 000 km during the night and 4000 km during the day.

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III. — MEASUREMENTS OF THE ATMOSPHERIC NOISE OF TERRESTRIAL ORIGIN

(*a*) *Theoretical studies of noise characteristics*

Researches have been made concerning the signification and the physical meaning of the log-normal probability-distribution law for atmospheric noise amplitudes observed at the output of a linear amplifier. R. Fortet (1) made, on this subject, some remarks of a fundamental character ; he applied the principle that, if a physical quantity is distributed according to a log-normal law, this quantity may be considered as the *product* of a great number of independent variates.

G. Foldès (2) thinks that, reascending the chain of atmospheric noise causes up to formation of thunderstorm clouds, it might be

possible to find a physical explanation which may give a starting point for new studies of the mechanism of cloud electricity until a disruptive discharge occurs. The C. T. R. Wilson's theory, as well as that of G. C. Simpson, give possibilities concerning this point.

A. Moles (3) studied the present state of knowledge on the possibilities of analysis and objectivation of a signal transmitted in a noisy channel, especially an acoustical channel. He showed, in particular, the necessity of adopting an absolute upper limit for the interfering noise in certain applications (esthetical message), although the concept of occupation, after Foldès, may be used in other problems (semantic message).

(*b*) *Experimental studies*

The numerous routine records of the mean level of atmospherics at the « Laboratoire National de Radioélectricité » during the period covering two solar cycles, contains informations that have not been systematically analysed with modern methods. It is proposed to enquire about the possibility of such analyses, which would give precious results, especially on the variation of atmospheric noise amplitudes at the lower frequencies, as a function of time and perhaps of geographical location.

On the basis of records at constant level, which were obtained during the period 1944-1955, G. Foldès established curves giving the diurnal variation of the minimum field required in Paris for radioteletype communications on 27 kc/s ; these curves refer to three months periods, respectively summer, autumn and winter. Such informations, obtainable only up to now by Thomas method, have been deduced from automatical and continuous records, with particularly simple and economical means.

These works, as well as the suggestions concerning development and new applications of constant level records, have been presented in the report of the working group established by Commission IV, at The Hague, under the chairmanship of A. W. Sullivan, now replaced by W. Q. Critchlow.

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Germany

N° 193. — Report of the National Committee to Commission IV

by A. Ehmert

Records of the atmospheric numbers were continued in Frankfurt, Hamburg (1), Kühlungsborn (2), Tübingen und Weissenau (3) and are just begun at Aachen (Meteorologisches Observatorium des Deutschen Wetterdienstes, Prof. Dr. H. Israel, Aachen, Pipinstrasse (12). Comparable Records at several of these stations are secured (4).

Cathod-Ray-Direction finding is used at Aachen, Kühlungsborn and at Weissenau. Waveforms were recorded at Kühlungsborn by triggering and at Weissenau using a high speed drum.

Records of very low frequency perturbations down to 3 cps were taken in München (Elektrophysikalisches Institut, Walter-van-Dyck-Platz 1, Prof. Dr. W. O. Schumann). Periodical sinelike oscillations of 3 cps and 9 cps were found with normal antenna and with coils on iron core (5).

Magnet-type recording of Whistlers is installed at Kühlungsborn.

Waveform Studies showed lowering of reflection height at sunrise by 10 km. Sunlight passing just above the ozone layer causes at sunrise electron detachment in 75 km height. The wavelength is greater than 300 Å (3).

The high intensity of solar cosmic radiation in the night of 23/24th February 1956 caused even in lower latitudes strong absorption of atmospherics on the nightside of the earth (6, 7) by electron densities of the order of 1 to 5 electrons per ccm in the region from 70 to 90 km. Most of these electrons undergo attachment.

The accumulated attached ions were numerous enough to deliver by collisions a sufficient number of shortly free electrons to

continue absorbing of atmospherics throughout the night after the impact of solar cosmic rays. At sunrise detachment increased the abnormal absorption of low frequencies (4).

Statistics on daily and annual variations of atmospheric noise at 4°, 27 and 14 kc/s show in all seasons a high influence of the D-layer and solar activity (8). Sunrise effects were investigated (2, 6, 8).

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Japan

N° 200. — Report of the National Committee to Commission IV

prepared by A. Kimpara

May 26th, 1957

This report summarizes the work on Atmospherics which has been carried out in Japan since that reported to the XIth General Assembly in 1954. The main topics are the waveforms of atmospherics relating to radio propagation and meteorology, the lightning discharges and the waveforms of atmospherics, the characteristics of terrestrial radio noise, the whistling atmospherics, the sudden enhancement of atmospherics, counters for local lightning

flashes and preparation for I.G.Y. The major part of the work has been done at the Research Institute of Atmospherics, Nagoya University under Prof. A. Kimpara, Mr. H. Ishikawa, Mr. K. Sao, Mr. A. Iwai and Mr. T. Kamada, at the Technical Research Laboratory of Japan Broadcasting Corporation under Mr. Fujita and Mr. T. Nakamura, at the Overseas Telegraph and Telephone Services under Dr. Shinkawa and Dr. Y. Furuhashi, at the Radio Research Laboratories of the Ministry of Post under Dr. Y. Aono and Mr. T. Ishida, at the Radio Regulatory Bureau under Mr. T. Morimoto and Dr. F. Minozuma, at Tokyo University under Dr. Taki, at Waseda University under Dr. H. Hirayama, at Iwasaki Tsushinki Co. under Dr. H. Seki and at the Meteorological Research Institute under Mr. N. Kitagawa.

I. — Waveform of atmospherics

Based on the results of observation and the experiences in 1950-1956, A. Kimpara (1) classified and interpreted the waveform of atmospherics according to the mechanism of discharge at the source and the conditions of propagation paths, and made clear the correspondence to Rivault's and Pierce's classifications. Under favourable propagation conditions at night he could locate thunderstorms within 3000 km at a single station by observing simultaneously waveforms and direction ; he found also that the limit of distance over which the height of reflection layer and the distance of source can be evaluated from waveforms is 300 km, and the height of reflection layer is 80-90 km at night.

In accordance with Budden's waveguide mode theory, K. Sao (2) investigated to derive the frequency spectrum of atmospherics radiated from return streamers. He (3) found the height of reflection layer for daytime atmospherics to be 65 km from waveforms in the distance less than 2000 km, and he (4) found also sometimes two reflection layers at about 5 km apart from waveforms at night.

T. Nakai (5) derived the frequency spectrum of atmospherics from waveforms of return streamer type by applying Fourier integral. He (6) evaluated also the reflection height at night in summer to be 85 ± 5 km from waveform records.

II. — The lightning flashes and the waveforms of atmospherics

In order to investigate the fine structure of lightning strokes, H. Ishikawa, M. Takagi and T. Takeuchi invented a high speed rotating camera of high quality. It consists of 12 rotating mirrors, whose peripheral velocity is 900-1500 m/s, 11 cameras, which have lenses of f : 1.4 and 1.2 and installed opposite to mirrors, and 5 stationary cameras. Every summer they operated this camera simultaneously with waveform recorders (8) and a field meter, and took many lightning stroke records, among which there was a clear photograph of stepped leader stroke, and they (7) found that the waveform of pulses emitted from cloud or air discharges are symmetrical and those due to strokes to the earth asymmetrical, and that in Japan β type stepped leader occupies 90 % and χ type 10 %, and they suggested that some of the slow discharge processes in thunderclouds are mainly composed of corona discharges of various types between two charge centres in the cloud.

N. Kitagawa (9) made simultaneous observations with waveform recorders and an electrostatic flux meters every summer and concluded that the stepping process are observed on both stepped and dart leader strokes, with corresponding successions of pulses on waveform records, and that streamers, which generate cloud discharges and J-field changes, proceed continuously without stepping process and they are caused by the inhomogeneous distribution of negative charge in the cloud.

III. — Meteorological relations of atmospherics

A. Kimpara (10) made an extensive series of simultaneous observations of waveform and direction finding of atmospherics at three stations in Japan from 1952 to 1954. He made clear the correlation of origins of atmospherics with thunderstorms, showers, snow storms, cumulo-nimbi, cyclones, tropical depressions and storms, typhoons, fronts, troughs in the upper atmosphere and so on; he showed the distribution of atmospherics in the Far East as well as in the Western Pacific all the year round, especially in tropical and subtropical Asia and Australia, the Indonesia Islands, the China Sea including the Philippines and so on, and gives a reasonable interpretation of the distribution of origins from meteorological point of view.

IV. — The characteristics of terrestrial radio noise

In order to find a reasonable objective method of measuring intensities of atmospherics which gives good correspondence to Thomas' method, A. Kimpara, H. Shinkawa, T. Fujita, Y. Aono, Y. Taki and F. Minozuma made a special committee, discussed the problem several times, and in October, 1956 they gathered five different measuring equipments at Ohira Station near Tokyo, and made simultaneous observations on HF and MF bands, accompanied by Thomas' method. As the characteristics and arriving time rate of atmospherics are fairly irregular, they have not yet reached a definite conclusion and they are continuing the experiment.

Dr. H. Shinkawa and Dr. Y. Furuhashi made a statistic measuring equipment for amplitude distribution of atmospherics by which they measured the probability simultaneously at six different threshold levels and got also cumulative distribution curves. They made further a pulse generator and measured the amplitude distribution. This equipment includes a white-noise generator from which all combination of fixed and random frequency and amplitude. They found that amplitude distributions of noise are generally logarithmic normal and they are examining whether this result bears resemblance to atmospherics.

Y. Aono and T. Ishida (11, 12) measured amplitude probability distribution of atmospherics at 3.5 and 10 Mc/s, and found that it can be approximated by the superposition of the Rayleigh and the log-normal distributions corresponding to random and impulsive noises respectively of which log-normal one increases at night and disappears in the daytime.

H. Seki and Y. Furuhashi made a random pulse generator to simulate the HF noise for the testing of response of HF receiver against quasi-impulsive noise ; both amplitude and phase are modulated independently so that the simulation is achieved completely.

T. Fujita (13) and T. Nakamura made a noise measuring equipment on MF band to measure the simultaneous amplitude probability distribution function of four levels at the detector of a radio receiver as well as the root-meansquare value at the intermediate frequency amplifier. Using a pulse generator, they found that the annoyance of pulsive noise for radio broadcasting programs can

be represented better by the root-meansquare value of noise than the quasi-peak one.

Apart from B. E. Burgess' proposal, F. Minozuma (14) introduced requirements for the radio noise measuring instrument which includes the characteristics of bandwidth and time constant versus detector efficiency ; he made a complete description of the theoretical and experimental study on radio noise too, and there he showed charts for city noise and atmospherics in some principal regions of Japan, general estimation of man made noise, and its characteristics as well as its counterplans.

A. Kimpara and T. Nakai have just finished a similar noise measuring equipment on LF band and are going to operate it.

V. — Whistling atmospherics

A. Kimpara, A. Iwai and J. Outsu (15) have made routine observation of whistling atmospherics at Toyokawa (geomag. lat. 24°5) since May 1956, and at Wakkanai (geomag. lat. 35°3) in summer 1956. Routine observation at Wakkanai will begin in July 1957. They found that the whistling atmospherics are observed at Toyokawa very often in winter, but rarely in summer ; at Wakkanai often even in summer. In general whistlers are observed at night, especially for two hours about sunset on days where solar flares or magnetic disturbances are observed. Dispersions of whistlers at Wakkanai are 45-110 $s^{\frac{1}{2}}$ and those at Toyokawa 15-70 $s^{\frac{1}{2}}$.

VI. — Sudden enhancement of atmospherics

Since 1955 A. Kimpara (16), H. Ishikawa and T. Kamada have studied the correlation of sudden enhancement of atmospherics with the occurrence of solar flare. They compared enhancement at 10, 21 and 27 kc/s with outbursts of solar radio waves at 3750 Mc/s, solar flare effects on magnetograms, fade-out phenomena on short wave radio communications, and found that these abnormal phenomena in geophysics are intimately correlated with enhancement at 21 and 27 kc/s and no enhancement or heavy decrease at 10 kc/s. The enhancement of atmospherics due to other meteorological phenomena shows the same tendency for all 10, 21 and 27 kc/s and therefore enhancement due to solar flares can be discriminated by this means even when the station is not in the daytime.

VII. — Local lightning flash counters

In order to devise the most appropriate counter A. Kimpara, T. Kamada, A. Iwai and K. Ito (17) made 16 different types of counters in 1954, and they made observation with these counters every summer, collaborated by H. Ishikawa, M. Takagi and T. Takeuchi, the lightning discharge studying group, at the same station. The final conclusion they reached recently is as follows. Bandwidth 1-80 kc/s, threshold field intensity 1.5 V/m, maximum rate of operation 1.25 per sec. When the lightning discharges approach within 10 km, higher frequency components predominate, and so 80 kc/s is required as upper limit. To avoid man-made noise lower limit 1 kc/s is necessary, though the lower the frequency the more faithful the coincidence between records on counters and those on flux-meters or actual flashes.

Abstracts of papers submitted to the XIIth general assembly

N° 39. — Some results of simultaneous measurement of atmospheric noise intensity by various meters, A. Kimpara, H. Shinkawa, T. Fujita, Y. Aono, Y. Taki, F. Minozuma.

Abstract. — Measurement of atmospheric noise intensity was carried out by means of five different meters. The results were compared on the high frequency atmospheric noise, but we could not reach any conclusion as to which was the best method or the quantitative relations between them, because atmospheric noise has a rather complicated nature. This study must be continued to form the conclusion as to which is the best method as the basis of radio communication.

N° 38. — The Waveform of atmospherics in the far East, A. Kimpara, Nagoya University, Japan.

This paper is the summary of the recent study on the waveform of atmospherics observed in the Far East. The waveform is classified as follows : stepped leader stroke type, partial discharge within cloud type, successive discharges among clouds type, return streamer type, multiple stroke type, slow tail type, reflection echo type and long train type. General features of every type of waveform in the daytime and at night, frequency of every type of waveform in the daytime and at night, frequency characteristics and their dependence on distance are fully discussed.

N° 40. — Measurement of amplitude probability distribution of atmospheric noise in high frequency band, T. Ishida, Radio Research Laboratories, Japan.

Abstract. — Measurement of the statistical characteristics of atmospheric noise was made five times for three years from 1955 to 1957 using a new

designed equipment. In general the amplitude probability distribution of atmospheric noise in high frequency can be approximated by the superposition of the Rayleigh and the log-normal distributions. The log-normal distribution has a remarkable diurnal variation.

N° 41. — On an investigation of whistling atmospherics in Japan, A. KIMPARA, A. IWAI, J. OUTSU, Nagoya University, Japan.

Abstract. — Since May 1956, continuous observations of whistlers have been made at Toyokawa. Simultaneous observations at Toyokawa and Wakkanai were made for one month beginning 13 July 1956.

The results obtained in these observations were essentially similar to those reported by Storey, except systematic diurnal variations of the dispersion such as 20 $s^{\frac{1}{2}}$-25 $s^{\frac{1}{2}}$ and preceding clicks of the tweek type atmospherics accompanying short whistlers.

N° 37. — Lightning mechanisms and Radiation of atmospherics, H. ISHIKAWA, Nagoya University, Japan.

Abstract. — The records of electrostatic field change, and waveform of atmospheric, each pair obtained at the same moment of a cloud discharge, have been investigated and the possibilities have been suggested that some of the slow discharge processes in thunderclouds are mainly composed of corona discharges of various types between two charge centres in the cloud.

N° 36. — Field-Changes due to lightning discharges and their discharge mechanisms, N. KITAGAWA, Meteorological Research Institute, Suginami, Tokyo, Japan.

Abstract. — Field-changes due to lightnng discharge are recorded by operating simultaneously two apparatus having different ranges of time resolution. The detailed features of the field-change due to the leader to the ground stroke are described, and some of its discharge mechanism is discussed. The field-changes due to a cloud flash and a junction process in a flash to ground are also investigated and the discharge mechanism, which cause these changes, are explained being correlated to the charge distribution in the cloud.

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16. A. KIMPARA. — On the sudden enhancement of atmospherics. *Bul. Res. Inst. Atm. Nagoya Univ.*, Vol. 6, nº 1-2, 1956.

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Morocco

Nº 170. — Report of the National Committee to Commission IV

(*Translation*)

Statistical records on 27 kc/s with an anemocinemograph and a balistegre have been continued.

Goniometric surveys with high-resolution self recording direction finder (system Bureau) are made in a routine program.

Special records and particular observations are sent daily by radiotelephone to the « Laboratoire National de Radioélectricité »

in Bagneux and by telephone to the meteorological service of the airport of Rabat-Salé.

Enhancements of atmospherics are compared with traffic perturbations observed by the « Centre des Liaisons Radioélectriques » in the interval 4-18 Mc/s. Interesting correspondances were found during the formation of SID.

A cathode ray tube direction finder is used for thunderstorm localization, in connection with whistlers studies. This activity, beginning at the end of 1954, gave some results at the end of 1956. Magnetic recordings are made every night, hourly, during 5 minutes. Improvement of this equipment follows its course.

New Zealand

N° 159. — Report of the National Committee to Commission IV

A joint programme of work on Whistlers and Dawn Chorus is being carried out by the Dominion Physical Laboratory and the New Zealand Broadcasting Service.

(*a*) Whistlers

Regular magnetic tape recordings of whistlers commenced in July 1955 at quiet sites near Wellington and Dunedin, 600 km apart along a geomagnetic meridian, with the assistance and cooperation of Dartmouth College, N H., U. S. A.

These stations are very nearly magnetically conjugate to one operated for Dartmouth College at Unalaska, Aleutian Islands. Strong support has been given to Storey's theory of the propagation of whistlers along magnetic lines of force, by the simultaneous observation of specific whistler trains at Unalaska and in New Zealand, and by the generally high association of short whistlers at Unalaska with long whistlers in New Zealand (about 45 % on the average) (1).

From the diurnal variation in the occurrence of whistler trains, which is strongly peaked at 0200 local time, it has been inferred that the whistler energy is absorbed to a detectable extent at the top of the whistler path.

No whistler trains have yet been observed near noon.

An experiment to measure the angle of arrival of whistlers, using aerials spaced 15 km apart, has been proposed (2).

(*b*) Dawn Chorus

Dawn Chorus signals have been observed to occur simultaneously, to within 0.01 sec., at Wellington and Dunedin, 600 km apart (3). From a study of the correlation of observations in New Zealand and those elsewhere, it has been concluded that dawn chorus signals are propagated in a similar fashion to whistlers, and that they are probably initiated by the entry of charged particles into the outer ionosphere at times of magnetic disturbances (4).

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Poland

N° 240. — Report of the National Committee to Commission IV

In 1952 the State Hydrological Meteorological Institute resumed the research on radio noise of terrestrial origin. This research had been interrupted by the war. Noises, or rather atmospheric statics on 27 kc/s are recorded.

The directions of arrival of atmospheric statics will also be registered automatically beginning with 1957. It is planned to put in Poland 3 direction finders into operation.

Besides this, strong local atmospheric discharges are recorded in some localities in Poland and theoretical and experimental work is being done on the character of electrical statics for communication purposes.

Sweden

N° 216. — Report of the National Committee to Commission IV

(Harald NORINDER)

Since 1952 the atmospheric noise level on 45 kc/s is being measured at the receiving station of the Board of Swedish Telecommunications at Enköping (17°08^t E 59°35^t N). For the measurements two different methods are used, the Thomas method and an automatic recording method nearly identical with the method recommended by the U. S. Joint Coordination Committee on Radio Reception.

A description of the measuring equipment and results obtained during the year 1952 is to be found in the document n° 230, C.C.I.R., London 1953, « Preliminary results obtained by two different methods for measuring atmospheric radio noise ».

At the the Institute of High Tension Research, University of Uppsala, atmospherics of terrestrial origin have been investigated in the vicinity of Uppsala by using 4 field stations, one situated at the institute and three other ones at distances from the institute of respectively 7, 12 and 17 km.

The principal aim of the investigations has been to analyse, if possible, the simultaneous variations of the electromagnetic field in the vicinity regions of lightning strokes. Each station has been equipped with recording sealed-off cathode-ray oscillographs. To locate arriving thunderstorms direction finders of the cathode-ray oscillographic pattern have been used.

The distances to the lightning discharges and their forms have been determined by outside observers, and during the thunderstorm seasons of 1955-56 by photographs of the lightning strokes by a day-light camera. The photographs were taken, if possible, simultaneously with the oscillograms of the respective field stations, at which the oscillograms were synchronized by a special arrangement.

The main part of the investigations was concentrated to analysis of the simultaneous variations of the magnetic field components measured by frame aerials in vertical, horizontal or 45° planes against the earth's surface. The stations were characterized by open field conditions and homogeneous resistance of the soil —

deep clay layers —. Investigations of the electric field components in the vicinity of lightning strokes have also been carried out simultaneously at two stations with open antenna systems.

One of the stations situated at the border of a lake was equipped with a long insulated linear antenna and two loop antennas on the bottom of the lake. The station is characterized by a very low noise level from electric power distribution systems. The special purpose of this station was simultaneous investigations of both local and long distant atmospherics recorded with the open antenna method — the electric field component — as well as with the loop method — the magnetic field component.

The station situated at the lake has been used for studies of whistlers and their relation to lightning discharges. These investigations have been carried out by using the long linear antenna on the bottom of the lake — north-south direction — in combination with direction finder observations. The whistlers were taken on a magnetic tape recorder. Very pronounced time relations between individual lightning strokes and whistlers were obtained. In addition, the station is provided with two vertical loop antennas in north-south and east-west directions. The loops are matched to amplifiers through an impedance transforming device. Tests show that the receiving properties of this system for whistlers are very satisfactory. Results of whistler investigations are not yet published, but the intention is to report verbally at a discussion when the whistler problem will be dealt with at the Assembly at Boulder.

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The results of the other investigations mentioned above are given in the following publications :

Harald Norinder and Walter Pucher. — Field intensities and charge densities in thunderclouds. *Arkiv för geofysik*, Bd 2, n° 5, Stockholm 1954, pp. 97-107.

Harald Norinder. — The wave-forms of the electric filed in atmospherics recorded simultaneously by two distant stations. *Arkiv för Geofysik*, Bd 2, n° 9, Stockholm 1954, pp. 161-195.

Harald Norinder. — Magnetic field variations from lightning strokes in vicinity of thunderstorms. *Arkiv för Geofysik*, Bd 2, n° 20, Stockholm 1956, pp. 423-451.

Olov NORINDER and Edgar KNUDSEN. — A new method of measuring rapid magnetic field variations from atmospheric electric discharges by using a loop system on the earth's surface. *Arkiv för Geofysik*, Bd 2, nº 23, Stockholm 1956, pp. 481-499.

The following papers with their summaries are being printed in *Arkiv för Geofysik*, Royal Academy of Sciences, Stockholm, and some of them are supposed to be available in Commission IV at the Assembly at Boulder.

Harald NORINDER and Edgar KNUDSEN. — Predischarges in relation to subsequent lightning strokes (Submitted paper).

Summary. — The variation features of predischarges in lightning strokes have up to now been neglected in researches. To a great extent this is caused by the complicated and very extended variation time of lightning discharges. These consist of three stages :

(1) the predischarges when during time period of up to the order of 10 milliseconds, the ionisation is starting in the lightning channel regions ; (2) the main and partial discharges with their rapid increase of the fronts within periods of sometimes only a few microseconds ; (3) the after-variations with a decrease of the lightning currents sometimes during many hundreds of microseconds. The authors have developed special methods for investigation of the variation features of the predischarges. They discovered that two different variation forms occur. The variation features of the predischarges were analysed both from physical and statistical points of view.

Harald NORINDER and Burghardt VOLLMER. — Variation forms and time sequence of multiple lightning strokes (Submitted paper).

Summary. — In the analysis of atmospherics from lightning discharges the time sequence and variation forms of multiple strokes have earlier been neglected. This problem is important from several points of view. It is stressed when the noise level from lightning strokes is carried out by counting the number of strokes over a given land region.

By a special sweep recording circuit the variations and the time sequence of multiple lightning strokes have been analysed at the Institute during the thunderstorm seasons of 1953-55. The results were obtained by using movable vertical frame aerials in combination with amplifiers and cathode-ray oscillographs. The method allowed an analysis of the magnetic field components of multiple lightning strokes.

Harald NORINDER and Edgar KNUDSEN. — Atmospheric electric discharges from distant snow squalls and occlusion fronts (Submitted paper).

Summary. — Atmospherics or sferics of a new type emanated from electric discharges in clouds containing snow and ice particles discovered at the Institute of High Tension Research some years ago have been investigated with regard to their sources and variation forms. The sources were located by two direction finders placed on a base line. The variation forms were analysed by cathode-ray oscillographic records. They showed quite another regularity than sferics from lightning strokes and were

lacking superimposed rapid variations. At distances of 300 kilometres the field forces of the new sferics attained 25 % of the corresponding values of sferics from lightning discharges.

Several other papers covering the above-mentioned investigations are in preparation and will be printed later in *Arkiv för Geofysik*.

Switzerland

N° 141. — Report of the National Committee to Commission IV

Prof. J. LUGEON

Prof. Dr. Jean Lugeon has continued the registrations of the atmospherics with radiogoniographs operated at 27 kc/s on the meteorological Office at Zürich and the meteorological station of Payerne. The basis of 131 km between these 2 stations allowed to measure the azimuths and to obtain the geographical positions of centers of atmospherics far away, just as the positions of near thunderstorms. A great deal of international collaboration has been undertaken in this field between the meteorological offices of Great-Britain, France and Switzerland. The result of a confrontation of the methods used in these three countries and the comparison of the Radiogoniometry with visual and auditory informations relating to thunderstorms on a great part of the European Continent, gave the possibility of precising the ideas on the use of the sferics-methods to the synoptic meteorology and particularly to the security of the aerial navigation.

Mr. Lugeon has organized at Zürich from the 29 to the 31 october 1956 the second world-wide Symposium on atmospherics in order to co-ordinate the world-wide network of sferics during the International Geophysical Year.

Some important recommendations for the application of the different actual methods for the exploration at great distance of the thunderstorms and electric storms, generators of sferics, have resulted from this international session. In some cases it could be shown that the precision of Radio-locating was in the order of 10 km for a distance of 1000 km. It was shown also that some lapses of the meteorological system due to the lack of human observation could partly be filled in with the observation of thunderstorms at a great distance by the methods of atmospherics.

We remind you that the Prof. Lugeon organises during the I.G.Y. a radio meteorological station at 80° at north latitude at the Spitzberg Archipelago with the collaboration of Sweden and Finland. Important results of the registrations made there in order to perfect definitively the problems of the transmission on great waves-lengths during the polar day and night might be expected. Also, the problems of the crepuscular periods at the beginning and at the end of the polar night will be carefully studied.

United Kingdom

N° 125. — Report of the National Committee to Commission IV

General

Recent work in the field of interest of Commission IV can be reported mainly under the programme headings for the XIIth General Assembly, listed in Bulletin n° 101.

1. — The Use of Waveforms of Atmospherics for Studying Radio Propagation

Most investigations of the waveforms of atmospherics yield information on both radio propagation phenomena and on the characteristics of the source. Studies which have more bearing on the first topic will be reported here ; those dealing mainly with the second will be in the following section.

At the Cavendish Laboratory there has been continued interest in the use of atmospherics to test the validity of the waveguide theory of propagation developed by K. G. Budden. J. Chapman and E. T. Pierce (1) have discussed the spectra corresponding to various types of waveform. At short distances from return strokes (say 200 km) differences in type or in spectrum must be ascribed to differences in the source. At considerably greater distances propagation influences are predominant. Detailed comparisons were made between atmospherics at 10 and 18 kc/s and Budden's theory. Qualitatively there was good accord, but quantitatively the agreement was less satisfactory. Chapman

and Pierce (2) have also studied further the systematic differences between atmospherics from sources in different localities at the same distance from the observing station. They find that differences in the spectra, derived from measurements at several fixed frequencies between 0.65 and 27 kc/s, can be used to render more precise the results of earlier work based solely on differences in waveform type.

F. Hepburn (3), at the University of Nottingham, has also been able to explain waveforms qualitatively in terms of Budden's theory, particularly in respect of the changes with distance and time of day. Differences in waveform with direction of propagation have been observed. Earlier work, started with Pierce (4), on an explanation of « slow tails » has been continued, and good agreement with theory has been found (5).

F. Horner and C. Clarke (6) of the Radio Research Station have studied the use of waveform recording in the possible location of thunderstorms from a single station. The complex nature of many of the « echo-type » waveforms which are used for estimating the distance of the source greatly increases the difficulty of applying the technique in a rapid, routine, operational procedure. Evidence was obtained of simultaneous partial reflection of waves from two layers at a separation of a few kilometres in height.

F. W. Chapman at King's College, London, has continued his waveform and spectrum work in the frequency range 40 c/s to 16 kc/s, using magnetic tape recording to study sustained types of disturbance which could not be resolved adequately by the « time-base » method. Improved dual-channel recorders are now being used. New results include the identification of two distinct types of slow component in some atmospherics. An analysis has been made of the polarity and other characteristics of these components in relation to the nature of thes source and the propagation path. The laws of propagation of radio waves at frequencies down to 40 c/s have been derived (7, 8).

2. — Relationship between Atmospherics and Lightning Discharges

E. T. Pierce (9, 10, 11) has described the results of a long study of the field changes due to lightning. The magnitude and nature of the radiation fields were discussed. He has also studied the factors influencing the design and reliability of lightning flash

counters (12) and the use of atmospherics as indicators of world-wide thunderstorm activity (13). He has discussed the optimum frequency at which observations should be made if significant results are to be obtained from a limited number of stations. M. I. Large and E. T. Pierce (14) have studied natural point discharge currents, and Large (15) has investigated, experimentally and theoretically, the intensity and spectrum of the radio interference produced by corona discharge from a single point. There is close similarity between natural point discharges and those observed in the laboratory.

The nature of the leader stroke of a lightning discharge is still a subject of speculation. C. E. R. Bruce, of the Electrical Research Association, has reaffirmed his earlier theory that the mechanism of the pilot streamer and leader stroke involves a transition from a corona-type to an arc-type discharge (16). This theory is an alternative to that of Schonland (17) which does not involve a corona discharge.

J. S. Forrest, of the Central Electricity Authority has recorded waveforms of atmospherics in an effort to obtain statistical data on the number of lightning flashes to earth per unit area, but the interpretation of the records has proved difficult.

A. G. Edwards (18) has measured the frequency spectra of atmospherics at very low frequencies and has found them to be consistent with the assumption that they originate in return strokes. F. Horner has studied the characteristics of narrow band noise at V.L.F. and H.F., in relation to the characteristics of lightning discharges. This work confirms that V.L.F. noise originates almost entirely in return strokes and provides information on the fine structure of the noise. The origin of H.F. noise is not so clear, but theories based on the assumption that the stepped-leaders preceding return strokes are the main sources are not consistent with the character of the noise recorded in England.

The spectrum at the source, of different types of discharge, has also been deduced by F. W. Chapman from measurements at a distance, allowing for propagation effects.

3. — Measurement of Characteristics of Atmospheric Noise

Measurements of noise at high frequencies (2-20 Mc/s) have been continued, as part of the programme of the Radio Research

Station, at several locations distributed over the world. The method used is that in which the intelligibility of a locally-generated signal mixed with the noise is estimated. The same method has been used at low frequencies (15-500 kc/s) at some of the stations.

The detailed characteristics of the noise at very low frequencies (10-30 kc/s) in England have been investigated by F. Horner and J. Harwood (19). The noise could be described in terms of the amplitude probability of the envelope voltage (the fraction of the time for which various thresholds were exceeded) and the amplitude distribution of the peaks in the envelope (number of pulses per second exceeding each threshold). Noise at high frequencies was more difficult to describe. It consisted of bursts having, in themselves, characteristics similar to those of fluctuation noise. The statistical properties of the envelope of these bursts are required, rather than those of the noise voltage itself, and these are being studied. Techniques for recording the noise on magnetic tape have been developed.

Some noise measurements using highly directional aerials have been made by the British Post Office. The results have shown to what extent the geographical distribution of noise sources can introduce variations in the performance of a long-distance H.F. communications circuit.

Continuous observations of the integrated noise level at 10 kc/s have been made by F. W. Chapman, and multipen recorders are being installed for simultaneous measurements at a number of frequencies in the range 10 c/s to 10 kc/s.

4. — Whistlers

The sustained types of disturbance known as « tweeks », « short whistlers » and « long whistlers », have been studied by F. W. Chapman. It has been found that the theory of a simple specular reflection of waves between the earth and the ionosphere, as an explanation of a « tweek », does not hold for the initial stages of the disturbance.

5. — I.G.Y. Programme

The I.G.Y. programme on atmospheric noise is largely a continuation and extension of investigations which are already in

progress and described in preceding sections, notably on the measurement of atmospheric noise and waveforms of atmospherics. The noise programme will be extended by recording detailed characteristics of noise at Singapore, Malaya and Ibadan, Nigeria, using the techniques already in use at the Radio Research Station, England. It is hoped that noise-power recorders of the type developed by the National Bureau of Standards will also be available.

Arrangements are in hand to facilitate the simultaneous recording of waveforms at several stations in Europe, and to identify, subsequently, the corresponding waveforms on the different records. This type of co-operative programme has been advocated by U.R.S.I. for many years and, it is hoped, will be stimulated by the occurrence of the I.G.Y. The procedure may involve the transmission of time signals to all stations by radio, but preliminary tests have shown that the time-sequence of the atmospherics themselves is often sufficient to enable corresponding records to be identified. Information on storm positions will be available from the U.K. network of direction finders, organised by the Meteorological Office and an extension of this network has been proposed.

6. — Other Topics

Although not one of the specific topics for discussion at the XIIth General Assembly, work on the improvement of means for locating thunderstorms is relevant to all the topics. A full description of the direction finder used for this purpose in the United Kingdom has now been presented by C. Clarke and V. A. W. Harrison (20). The errors occurring with this type of instrument have been investigated by F. Horner (21). In particular the study of polarisation errors on atmospherics led to a series of measurements of bearings on the V.L.F. transmitter GBR (16 kc/s) from which it was concluded that propagation at this frequency varies with the direction of the path relative to the earth's magnetic field (22, 23).

E. T. Pierce read a paper on fundamental problems in radio direction finding on atmospherics at a conference on Meteorology and Radio-location, in Essen, in June 1956.

Further work on a means of measuring the distance of a storm from a single station by observing the high frequency energy

received has been described by C. Clarke and B. J. Byrne (24). Particular attention was paid to the effects of ionospheric irregularities on the accuracy of measurement.

A survey of some possible single-station techniques for locating thunderstorms has been made by E. T. Pierce (25).

7. — Abstracts of Papers to be submitted to the XIIth General Assembly

A. *Atmospheric Radio Noise at Frequencies between* 10 *kc/s and* 30 *kc/s*, by J. Harwood,

The characteristics of narrow-band V.L.F. atmospheric radio noise, and their variations with time and frequency, are described in terms of amplitude probability distributions of the envelope.

B. *The Relation between Atmospheric Radio Noise and Lightning*, by F. Horner.

Amplitude and detailed structure of atmospherics at very low frequencies have been compared with known characteristics of lightning discharges. The conclusion has been reached that nearly all the energy originates in return strokes from the ground.

Atmospherics at high frequencies have much longer durations than would be expected if they originated mainly in stepped-leader discharges. The main source may be a form of brush discharge which was suggested by Malan and Schonland.

C. *The Use of Magnetic Tape Recording for studying Atmospheric Noise Structure*, by C. Clarke.

In studying the amplitude probability distributions and other characteristics of atmospheric noise it is useful to be able to scan samples repeatedly at different threshold levels. This may be done if the noise is recorded on magnetic tape.

Noise at higher frequencies is converted to 10 kc/s, in a narrow bandwidth, and recorded on the tape. An amplitude range of 60 db can be recorded. Faithful reproduction of the original noise waveform is limited by imperfections in the tape and the recording equipment.

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U. S. A.

N° 298. — Report of the National Committee to Commission IV

During the period 1955 to 1957 this commission has taken part in all technical meetings of the U. S. A. National Committee and has maintained an active interest in the research being carried on in the field of Terrestrial Radio Noise. This report contains an account of the progress made by the major research organizations in the United States, a bibliography of papers presented at U.R.S.I. meetings.

I. — National Bureau of Standards, Boulder, Colorado

Instrumentation has been developed for measuring the cumulative distribution of the amplitudes and spacings of pulses and the instantaneous envelope of the atmospheric noise field. This equipment has been employed in observing the atmospheric noise field over a wide range of locations ranging from 9° north to 71° north latitude. In addition to the well known reduction of level with increase in latitude, the dynamic range of the noise was found to also decrease with an increase in latitude of the observing point.

The effects of varying the observing receiver bandwidth from 0.2 c/s to 1 kc/s bandwidth have been studied in detail at Boulder, Colorado. The effects of center frequency on the observed noise field have also been investigated from center frequencies of 1 kc/s to 10 Mc/s. In general the atmospheric noise envelope approached the Rayleigh distribution for bandwidth in the order of 0.2 c/s

at any observing center frequency. At wider bandwidths the dynamic range was found to increase considerably over that for a Rayleigh distribution. The dynamic range of the noise field appears to be greatest in the region of 10 kc/s with a decrease in dynamic range as frequency of observation is increased.

Details of these measurements have been described (1, 2), and an analysis has been made of some of the reasons for the observed results and the manner in which they are expected to vary with time and location.

The frequency spectrum radiated from a typical lightning discharge has been calculated based on photographic studies of discharges and measurements of the returned stroke current. These calculations are compared with observations of the radiated field (3). This effective radiated spectrum has been modified by the expected band pass characteristics of the transmission path (4). The resulting calculated frequency spectrum as a function of distance from the main thunderstorm center, is found to agree very well with measured spectra obtained at Boulder, Colorado during November and December of 1956.

The frequency spectrum of atmospheric noise from 10 c/s to 100 kc/s has been obtained by combining measurements by others (5, 6) with our results from 1 to 100 kc/s. The resulting shape (7) shows that there are two peaks in the frequency spectrum, one in the order of 90 c/s and the other at approximately 9 kc/s with a dip occurring in the region of 3 to 4 kc/s.

The effects of sources other than lightning discharges, have also been investigated (8), where it is observed that these extraterrestrial sources appear to have a maximum amplitude in the frequency range of 3 to 4 kc/s. It has been proposed (9) that this may result from a flow of energy in through the ionosphere in a manner similar to the outward flow or losses which produce the large attenuation of energy from terrestrial sources.

The performance of several typical radio systems in the presence of thermal and atmospheric noise has been analyzed in detail (10). The relative efficiency of the particular systems is found to be dependent upon the characteristics of the system being considered in addition to those of the carrier and the interference present.

In general, if the statistical amplitude and time distributions of the carrier and interfering noise are known, the performance

of a particular system can be predicted. The actual system performance determined in percentage character errors is in some cases directly related to the amplitude distribution of the interfering noise. Many systems however, modify the characteristics of the noise to such an extent that this direct relationship no longer holds, and the system performance is found to depart from the amplitude distribution of the interfering noise in a pre-dictable manner. In view of this it is considered that any attempt to obtain direct correlation between system performance and any simple characteristic of the interfering noise is not likely to succeed.

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II. — University of Florida, Gainesville, Florida

Primary effort was expended in the study of the probability distribution of atmospheric noise and its application in the pre-

diction of interference to radio communication systems. Studies were made of the correlation between the probability distribution of atmospheric noise and the interference observed in radiotelegraph, single and multi-channel frequency-shift radioteletype and A-M voice communications. In all cases a satisfactory degree of correlation was obtained.

A simple counter for registering lightning strokes over a limited area was developed for use by meteorologists.

III. — Oklahoma Agricultural and Mechanical College, Stillwater, Oklahoma

The goal of the sferic research at the Tornado Laboratory, Oklahoma A. and M. College has been to obtain a thorough knowledge of their relationship to the physics of thunderstorms. The identification of each of the three or four types of lightning discharges with the tornadic activity are as follows :

(1) Cloud-to-ground discharges : Most intense components from 5-20 kc/s, but also significant radiation from possibly hundredths of a cycle through the entire electromagnetic spectrum to at least the violet and possibly ultra-violet frequencies. The directional pipe from these strokes have been definitely identified at Oklahoma A. and M. College with visual pictures of the stroke surges.

(2) Cloud-to-cloud discharges : About the same as cloud-to-ground, the directional stroke tornadoes of ellipses, circles, and whirls ; it is relatively easy to identify this type of discharge on these records.

(3) Inner-cloud discharges in neighborhood of charge separation center : Intense components from 100 to 250 kc/s ; none below 100 kc/s that have been identified as such ; same radiation above 250 kc/s to visible spectrum. It is of the discharges that accompany a tornado type storm in which surges may reoccur at rates of 25 to 30 directional pips per second.

(4) Possible discharge of positive charge centers to regions above charge separation center ; several observers, including the author, have reported this type of discharge ; again visual camera recordings correlated in time-sequence with directional pips should disclose the nature of this discharge. This phenomena has only been observed one time from the Tornado Laboratory, and then

before a visual recordings camera was available. It is an interesting speculation that the energy detected at frequencies below 1 c/s might be radiated by this type of discharge.

(5) Other types of discharges may be possible, in which event a sferic residue in addition to the four types enumerated might disclose their existence.

Considerable progress has been made in developing the theory of whistler and dawn chorus emissions. Whistlers have been recorded simultaneously at points magnetically conjugate to each other and were to found follow the Eckersley dispersion law. Nose whistlers have been studied by Helliwell et al., and a theory proposed to explain their characteristics. Many variations in the form of dawn chorus have been observed including a periodic form, reporred by Dinger, that seems to suggest a connection with the whistler propagation paths.

A network of whistler recording stations has been established as part of the I.G.Y. Ionospheric Program.

V. — Bibliography of Papers Presented at Meetings of U. S. A. Commission IV

1. *The Effect of Atmospheric Noise on a Manual Radiotelegraph System*, R. F. Brown, University of Florida.
2. *The Effect of Atmospheric Noise on a Frequency-Shift Radioteletype System*, S. P. Herspeiger, University of Florida.
3. *Lightning Discharge Atmospheric Interference in Aircraft Communications*, M. M. Newman, Lightning and Transients Research Institute.
4. *Characteristics of High Frequency Discharges from Severe Storms*, H. L. Jones, Oklahoma A. and M. College.
5. *Atmospheric Noise Characteristics*, A. W. Sullivan, University of Florida
6. *A Statistical Model of Atmospheric Noise*, J. M. Barney, Convair Corporation.
7. *The Measurement of Recurrent Impulsive Noise*, A. Eckersley, D. B. Geselorvitz, University of Pennsylvania.
8. *A Probability Computer for Noise Measurement*, J. D. Wells, A. W. Sullivan, University of Florida.
9. *Whistling Atmospherics Observed at Washington, D. C.*, H. E. Dinger, U. S. Naval Research Laboratory.
10. *A Lightning Stroke Counter*, J. D. Wells, A. W. Sullivan, University of Florida.

11. *The Distribution of Atmospheric Noise and its Relation to the Log-Normal Law*, R. F. BROWN, University of Florida.
12. *Measurement of Atmospheric Radio Noise Moments*, F. F. FULTON, W. H. AHLBECK, National Bureau of Standards.
13. *Variations in the Statistical Character of Atmospheric Noise*, A. D. WATT, National Bureau of Standards.
14. *Audio Frequency Atmospherics* 10-900 *cps*, G. AARONS, Air Force Cambridge Research Center.
15. *The Sferic Characteristics of Thunderstorms*, H. L. JONES, Oklahoma A. and M. College.
16. *A New Whistler Dispersion Theory*, R. A. HELLIWELL, T. F. BELL, R. L. SMITH, Stanford University.
17. *The Application of Nose Whistlers to the Study of the Outer Ionosphere*, R. L. SMITH, Stanford University.
18. *Experiments on Whistlers and Associated Atmospherics*, J. H. CRARY, R. A. HELLIWELL, Stanford University.
19. *On the Dependence of Whistler Dispersion upon the Geomagnetic Latitude of the Generating Sferic*, M. G. MORGAN, H. W. CURTIS, Dartmouth; H. E. DINGER, U. S. Naval Research Laboratory; A. W. SULLIVAN, University of Florida.
20. *The Effect of Atmospheric Noise on Time-Division Multiplex Teletype*, A. W. SULLIVAN, University of Florida; R. F. BROWN, Convair Corporation.
21. *World-Wide Lightning Fields and Magnetic Pulsations in the* 1 *to* 150 *c/s Band*, P. A. GOLDBERG, University of Oregon.
22. *Results from the Tornado Season of* 1956, H. L. JONES, Oklahoma A. and M. College.
23. *Performance of Radio Systems in the Presence of Atmospheric Noise*, A. D. WATT, E. L. MAXWELL, National Bureau of Standards.
24. *Estimates of External Radio Noise Levels*, R. T. DISNEY, National Bureau of Standards.
25. *An Experimental System for Studying the Zeros of Gaussian Noise*, G. M. WHITE, Harvard University.
27. *Periodicity In Dawn Chorus*, H. E. DINGER, U. S. Naval Research Laboratory.
28. *Unusual Sferic Phenomena Observed During Tornado Season of* 1956, H. L. JONES, Oklahoma A. and M. College.
29. *Amplitude and Time Distributions of VLF Atmospheric Noise at Several Widely Spaced Geographic Points*, A. D. WATT, R. M. COON, V. J. ZEIRICKS, E. L. MAXWELL, National Bureau of Standards.
30. *The Comparative Interference Effects of Various Types of Radio Noise on an Idealized Communication System*, J. T. SUSS, University of Pennsylvania.

31. *A Simple Atmospherics Generator for Evaluation of Sferics Interference Reduction in Receivers,* M. M. NEWMAN, Lightning and Transients Research Institute.
32. *The Tracking of Severe Storms by the Radar-Sferic Method,* H. L. JONES, Oklahoma A. and M. College.
33. *Measurements of Frequency Distribution of Lightning Discharge Interference from* 15 *kilocycles to* 150 *Megacycles,* M. N. NEWMAN, J. D. ROBB J. R. STAHMANN, Lightning and Transients Research Institute.
34. *Impulse Overload of Radio Noise and Interference Meters,* A. ECKERSLEY, P. P. LOMBARDINE, O. STAVIK, University of Pennsylvania.
35. *Electromagnetic Radiation From Lightning Strokes,* E. L. HILL, University of Minnesota.
36. *The Transient Field of An Idealised Lightning Discharge,* J. R. WAIT, National Bureau of Standards.
37. *Moments of Atmospheric Noise Voltage Distributions,* F. F. FULTON, R. T. DISNEY, National Bureau of Standards.
38. *Notes on Variations in Whistler Activity and Associated Phenomena,* H. E. DINGER, Naval Research Laboratory.

Mr. Ratcliffe's Remarks at the Opening Ceremony

Commission IV is concerned with « Radio Noise of Terrestrial Origin ». We study the nature of the received noise and make deductions about its source and about how it is modified as it travels through the ionosphere and over the ground. At this General Assembly the following topics will be discussed at separate meetings.

At one we shall hear of the work being done to specify the strength and the statistical nature of our kind of radio noise in such a way that those who design radio communication channels shall know what interference they are likely to encounter at any time and place. We shall hear the conclusions of a working party set up at the last General Assembly to study these matters. At another meeting we shall discuss what can be deduced about the propagation of very low frequency waves from a study of atmospherics, and we shall hear the report of another working party set up to compare the results of different workers. Atmospherics originate in electrical discharges in thundery or stormy weather, often in lightning strokes, and one of our meetings will be devoted to discussing the relation between the source and the resulting atmospheric.

At the Sydney meeting in 1952 an explanation of the terrestrially produced radio noise known as a « whistler » was announced in Commission IV. Since that time, and particularly since the last General Assembly in 1954, a large amount of interesting experimental and theoretical work has been done on this subject. We shall devote a meeting to hearing about it, and we shall also hold a joint meeting on the subject with Commissions III and V who will be interested in some of the novel suggestions about the origin and propagation of different kinds of quasi-musical low frequency noise.

Minutes of the Meetings

First meeting, 2.00 p.m., Aug. 26th

The following programme for the remaining meetings was agreed.

Wed., Aug. 28th at 9.30 *a.m.*, Whistlers. Introductory summaryby Dr. MORGAN.

Contributions by Messrs. HELLIWELL, GALLET, DINGER, KIMPARA, MAEDA, RIVAULT, JEAN, HINES.

Paper nos 3, 4, 34 (Commission III).

Thurs., Aug. 29th at 9.30 *a.m.*, Whistlers, with Commissions III and V.

Thurs., Aug. 29th at 2.00 *p.m.*,

Waveforms and Propagation. Introduced by Dr. WORMELL.

Papers nos 4, 38, and an unnumbered paper by Dr. WAIT.

Fri., Aug. 30th at 2.00 *p.m.*, Characteristics of Noise. Introduced by William CRICHLOW.

Papers nos 39, 40, 126, 127, 254.

Mon., Sept. 2nd at 2.00 *p.m.*

Commission IV programme for I.G.Y.

Paper 151 and National Reports.

Brief reports on National Programmes by representatives present.

Tues., Sept. 3rd at 9.30 *a.m.*,

Waveforms and Sources.

Papers nos 36, 37, 115, 229, 230, 231, 239, and 267.

Wed., Sept. 4th at 9.30 *a.m.*

Final meeting to discuss resolutions.

Dr. WORMELL presented a brief report of the working party on atmospheric waveforms.

Mr. CRICHLOW presented a report of the working party on noise characteristics, and summarized Paper n° 254.

Discussion of these reports will take place at the appropriate meetings of the Commission.

The Chairman reported that attempts to collaborate with Commission VI on noise problems has been unseccessful. No joint meeting was proposed.

It was agreed that the working party on noise characteristics, under Mr. Crichlow, should consider C.C.I.R. Study Programme n° 96.

Second meeting, 9.30 a.m. on August 28th

Whistlers and related VLF phenomena

Presentation of papers

Dr. MORGAN summarized the main known features of whistler phenomena.

Dr. HELLIWELL reported a controlled experiment in which station NSS near Washington, D. C. pulsed at 15.5 kc/s, was received in Chile by the « whistler » mode.

Mr. GALLET suggested an explanation of some forms of VLF noise, based on interaction between solar corpuscular radiation and the earth's magnetic field.

Dr. HELLIWELL discussed Professor Maeda's theory on the deviation of the « whistler mode » propagation paths from the magnetic field lines.

Professor KIMPARA described the types of whistler received at low geomagnetic latitudes in Japan.

Mr. DINGER described some unusual VLF phenomena including periodic types of dawn chorus. Some types were observed simultaneously in Washington, D. C. and Ottawa.

Dr. RIVAULT discussed correlation between whistlers and atmospherics with certain types of waveform. Simultaneous observations in France and Kerguelen Islands were described.

Mr. JEAN showed an association between whistlers and a strong 5 kc/s component in the causative atmospheric.

Mr. HINES commented on a suggestion by Dr. Storey that the presence of heavy ions in the propagation medium could change whistler characteristics, and might explain some types.

Dr. MORGAN gave examples of multiple whistlers, apparently received by different paths, and showed some geographical distributions of dawn chorus.

Discussion

The time of day for maximum occurrence of dawn chorus was discussed. It appeared to depend on geomagnetic latitude.

Mr. DINGER had failed to record whistlers from atmospherics in local storms, but several speakers had had excellent correlation.

There was a discussion on the relation between frequency spectra of atmospherics and the likelihood of a whistler. A suggestion was made that different types of flash occurred in mountainous and flat country and that these were different as sources of whistlers.

A working party with the following membership was set up to consider terminology in this field, and if possible to report during the present assembly : Professor Helliwell (convener), Messrs. Morgan, Gallet, Rivault, Dinger and Storey.

Joint Meeting, of Commissions III, IV, V 9.30 a.m. on August 29th

Whistlers and related VLF Phenomena

Presentation of papers.

Mr. RATCLIFFE summarized the main features of whistlers and dawn chorus as presented at the Sydney Assembly.

Dr. MORGAN described the reception of whistlers at conjugate geomagnetic locations, and gave examples of multiple whistlers. He stated that whistlers had been positively identified with local lightning.

Prof. MAEDA summarized his theoretical conclusion that the ray paths in the « whistler » mode deviate outwards from the magnetic lines of force.

Prof. HELLIWELL gave a theoretical explanation of « nose whistlers », with experimental confirmation. He then described the reception of station NSS on 15.5 kc/s, at a site near the conju-

gate magnetic point. NSS appeared to be received all the time in the whistler mode. Important results related to multipath propagation, leading to split echoes and fading, and to poor correlation between reception of whistlers and strong NSS signals.

Mr. JEAN described simultaneous reception of whistlers at Boulder and Stanford University and showed relationships between whistlers and the spectra and geographical location of the originating lightning flashes.

Mr. GALLET propounded a theory of VLF hiss and similar phenomena based on the interaction of solar corpuscular streams with the earth's magnetic field. Various possible models of the exosphere were discussed and it was shown that some models led to qualitative explanation of preferred frequencies in hiss and of « hook-type » phenomena. The main conclusions were that the outer ionosphere was of a fibrous nature, that there was likely to be ionospheric layers outside the F-layers, that corpuscular radiation was the cause of some VLF noise and that the corpuscles could sometimes be in a continuous flow and sometimes in clouds.

Discussion.

Dr. MORGAN reported a correlation between « hook-type » whistlers and flashes in aurorae.

Dr. BIERMANN advanced reasons why the earth's magnetic field might extend effectively to only 5-10 earth radii.

Prof. RYDBECK asked what determined the gain parameter of the amplification of the radiation caused by the interaction of corpuscles and magnetic field. This was being studied by Prof. Helliwell who reported a preliminary conclusion that the corpuscular kinetic energy was far greater than appeared to be necessary to explain the observed levels of hiss. There was some discussion of whether the hiss originated in the outer ionosphere or in auroral regions ; both mechanisms appeared possible.

Dr. FUCHS reported observations of whistlers in Austria dating back to 1886 and reported a similar diurnal variation to that in more recent measurements. Prof. Kimpara suggested that the diurnal variation depended on geomagnetic latitude.

Mr. HINES outlined recent work initiated by Dr. Storey, which showed that the presence of ions could influence whistler spectra

at the lower frequencies and could give rise to a mechanism of propagation normal to the magnetic field.

Third meeting, 2.00 p.m. on Aug. 29th

Use of waveforms of atmospherics to study radio propagation

Presentation of papers.

Dr. WORMELL reported on the activities of the working party on atmospheric waveforms. Most workers agreed that there were four main types, and of these the regular peaked type observed at night had been most used for propagation studies. Dr. Wormell presented an example showing the considerable divergence in the interpretation of one waveform by different workers and stated that such disagreement was common. He described the criteria by which he himself judged the quality of a waveform.

Prof. KIMPARA surveyed the types of waveform record in Japan. His conclusions were in general agreement with those of other workers.

Dr. WAIT presented a summary of current theories of VLF propagation. He showed curves of both ground wave and ionospheric propagation as a function of frequency and distance, and explained how ray theory could be usefully extended to distances greater than the normal maximum 1-hop range.

Mr. JEAN showed how VLF ionospheric reflection had been studied over a wide frequency band by Fourier analysis of the ground and ionospheric waves of atmospherics, and compared the results with theoretical predictions.

Discussion.

Prof. NORINDER described experiments in which waveforms from the same lightning flash had been recorded at more than one station.

Dr. WAIT and Dr. WATT strongly expressed the view that such simultaneous recording was the only way to obtain propagation data from waveforms.

Mr. HORNER suggested that the meeting should decide what aspects of propagation could best be studied by waveform recording and might frame a recommendation. It was agreed that the

following people could consider this proposal : Messrs. Norinder, Jean, Watt, Wormell, Kimpara, Lauter, Izyumov and Horner.

Prof. LAUTER suggested that sunrise effects in the lower ionosphere should be studied.

Dr. WAIT gave some further data on the variation of attenuation with frequency.

Fourth meeting, 2.00 p.m. on August 30th

Measurement and description of noise characteristics

The report of the working party on noise characteristics was presented by Mr. Crichlow. It consisted of recommendations regarding the noise parameters which should be measured and the main features of the equipment which should be used for the measurements. These recommendations had been agreed among the members of the working party at meetings during the previous few days. Supporting information consisted of accounts of the methods and results of different workers.

Mr. RATCLIFFE suggested that the report might form the basis of an U.R.S.I. special report and this suggestion met with general agreement.

Mr. HORNER presented a report by Dr. Harwood with information on average voltages and amplitude distributions at very low frequencies. He then described his own records of the form of narrow-band noise from individual atmospherics at VLF and HF.

Dr. AONO presented data by Dr. Ishida on the amplitude probability distributions of noise at HF. There was some discussion on whether the low voltage ranges of the distribution approximated to a Rayleigh distribution when not contamintaed by set noise. Experience appeared to differ on this point. Mr. FOLDÈS presented information in support of the use of impulse flux as a parameter of the noise at low frequencies.

Mr. WATT discussed the relationship between amplitude probability distributions of noise and the interference caused by the noise to several types of communication service. He showed that in some instances it was possible to predict the behaviour of the services from the noise amplitude distributions.

Fifth Meeting on Sept. 2nd at 2.00 p.m.

Commission IV Work During the I.G.Y.

Reports of National Activities.

U. S. A. :

For whistler observations there would be 13 stations over a wide latitude range in the eastern American continent and groups of stations, totalling ten, in two areas in the Pacific at approximately conjugate geomagnetic locations. Records could be made for two minutes starting at 35 minutes past each hour, with timing accurate to ± 0.05 sec. The U. S. sferics network would operate every three hours to locate sources. It was not yet known where sferics data would be stored.

Primary data would be log sheets of the incidence of whistlers and other VLF emission, and would be sent to world data centres. The final repository for the magnetic tapes had not been decided but would presumably be a location in the United States. If analysis of tapes could be speeded up, spectrograms could be stored in the world data centres.

Professor Kimpara reported that he would send only tapes of particular interest to the Tokyo data centre.

Mr. Hines showed a sample of a spectrogram which had been obtained at the speed of the original tape record, using a new equipment. This instrument was expensive.

The programme of recording atmospheric noise was a 15-year programme which had been accelerated by the I.G.Y. About 14 stations in various parts of the world would be equipped with the C.R.P.L. type of noise meter. The apparatus would be supplied by C.R.P.L., and the receiving country would be responsible for the installation and operation.

U. S. S. R. :

The atmospheric noise I.G.Y. programme is being supervised by Prof. Pushkov of the Institute of Terrestrial Magnetism and Propagation of Radio Waves, near Moscow. The subjects studied are whistlers, waveform recording, location of sources by direction finding, measurement of electric field near lightning flashes and recording of atmospheric noise levels.

In reply to questions, Prof. Izyumov said that there would be at least three noise stations operating from 30 kc/s up to the MF band.

France :

The programme of recording the mean level of atmospherics and location of sources in various parts of the world would be continued. It had not yet been decided what data would be sent to the data centers.

Whistlers would be recorded for two minutes every hour just after the hour. Data will be exchanged with other workers. Some participation in the European scheme for simultaneous recording of waveforms was possible.

Japan :

There would be five stations recording, between them whistlers, locations of sources, waveforms, noise intensity and characteristics of sources.

Whistlers could be recorded for 2 minutes, at 5 and 35 minutes past each hour. Three DF stations would operate at 10 kc/s. Mean voltage of noise could be recorded at 10, 21 and 27 kc/s and more detailed characteristics at several frequencies from 50 kc/s to 20 Mc/s. Photographs of lightning flashes would be correlated with field variations.

Sweden :

Simultaneous measurements of field changes would be made near lightning flashes and at a distance. Whistlers would be recorded

Germany :

Direction finding equipment would be used at Potsdam. Waveforms would be recorded at Potsdam and Weissenau. Whistlers would be recorded at Kühlungsborn and near Frankfort. Average voltage and rates of occurrence of atmospherics would be measured at four stations at 14, 27, 40 and 130 kc/s. Particular attention would be paid to the variations in the shape of the diurnal curve.

United Kingdom :

The Thomas-type measurements of atmospheric noise would be continued. Three equipments had been made for measurement of average voltage, average power and several other characteristics of the noise. These would be located at Slough (England), Singapore (Malaya) and Ibadan (Nigeria). The last two would be close to C.R.P.L. noise recorders, operated as part of the United States Programme.

The arrangements for simultaneous recording of atmospherics in Europe were being sponsored by the United Kingdom. Dr. Wormell would coordinate the waveform observations and the British Meteorological Office would provide data on the location of sources.

Whistlers and the average voltage of atmospheric noise on 22 kc/s would be recorded at Cambridge.

Discussion.

Mr. RATCLIFFE suggested that the meeting should consider the following items.

1. Whether steps should be taken to ensure that the atmospheric noise data obtained at astronomical observatories be made available to radio world data centers.
2. Whether the European group recording waveforms and any other similar groups should seek recognition by U.R.S.I. in order that financial assistance could be obtained for the programmes.

It was agreed that recommendations should be drafted on these two topics.

Sixth Meeting, 9.30 a.m., Sept. 3, 1957

Waveforms of Atmospherics and Characteristics of Sources

Prof. NORINDER described the experimental facilities for waveform work in Sweden. They included loop receivers for whistler work and of particular interest was a large horizontal loop submerged in a lake. Characteristics of waveforms, particularly those from predischarges, were described. Cloud and ground discharges showed different ratios of the fields with different polarizations.

In view of the difficulty of designing a perfectly balanced loop, the insensitivity of the large submerged loop to the vertical electric field was questioned. It seemed desirable to check the balance on CW transmissions.

Mr. NEWMAN described facilities at Minneapolis, which were designed primarily for the generation of discharges. In addition, fields from natural discharges were being measured at several frequencies in the range 15 kc/s to 150 Mc/s. A device for reproducing atmospherics by scanning a picture of the waveform was illustrated. Attempts were to be made to induce lightning discharges by launching a long wire upwards from a boat, by means of rockets, towards a charge cloud. The high voltage equipment at Minneapolis was to be used in an attempt to generate whistlers.

There was considerable discussion on the relative merits of the rocket-launching experiment and measurements with kites or tethered balloons. There appeared to be some doubt whether there would be any significant difference between the two types of experiment.

Mr. DOHERTY described the results of Prof. Jones, in which certain characteristics of the fields from tornados were said to differ from those from normal thunderstorms. One of these characteristics was the fast rate of occurrence of impulses (>20 per second) at 150 kc/s from a tornado. Sources with this feature had been identified visually as tornados with a high degree of correlation. It was considered that more details of the experiments, such as the threshold level of the receiver, the distances of the receiving stations from the tornados and a clearer comparison of the corresponding phenomena for tornados and thunderstorms would be valuable.

Professor NORINDER described the characteristics of atmospherics originating in snow squalls. Similar phenomena were reported by Mr. Newman in the U. S. A. and in the Antarctic by Mr. Foldès.

Professor KIMPARA described his apparatus for recording waveforms and for taking simultaneous photographs of lightning flashes. He related the waveforms to the junction process and other similar phenomena of the discharge, and suggested the existence of a corona discharge within the cloud.

Mr. FOLDÈS described some theoretical work by French workers showing that a log-normal distribution coul dbe interpreted as a product of a large number of independent random variables. He suggested rasons why the noise from a single thunderstorm should be of this form, and said that the distribution could remain substantially log-normal for a group of several thunderstorms. Mr. Fulton and Mr. Watt both considered that the log-normal law should be regarded as only an empirical representation of the distribution over a limited amplitude range and that there was not necessarily a theoretical basis for it.

Mr. RATCLIFFE suggested that wave self-interaction in the ionosphere might seriously modify the waveform of an atmospheric, particularly its components at frequencies around 200 c/s. Mr. Dinger said there was some evidence of interaction of a strong atmospheric with a whistler.

Seventh Meeting, 2.00 p.m. on Sept. 3, 1957

Draft Recommendations

Draft recommendations on the following topics were discussed :

A. Characteristics of atmospheric noise, including replies to C.C.I.R. questions, and the suggested writing of an U.R.S.I. special report.

B. The recording of waveforms of atmospherics, including a proposal for support for further working groups in this subject.

C. A suggested symposium on whistlers and related phenomena.

D. A request to the International Astronomical Union for atmospheric noise data recorded at astronomical observatories.

E. Nomenclature for use in work on whistlers and related VLF phenomena.

Recommendation A was split into two parts, dealing with the answers to C.C.I.R. and the writing of an U.R.S.I. special report. These became Draft Recommendations IV/1 and IV/2 respectively for submission to the Plenary Session.

That part of recommendation B dealing with the setting up of working groups was approved and became Draft Recommendation IV/5. It was agreed that the part of Recommendation B which dealt with recommended experimental techniques for this

work should be revised and should form the subject of a note in the *U.R.S.I. bulletin*.

Draft Recommendation C was approved and became Draft Recommendation IV/3.

Draft Recommendation D was approved and became Draft Recommendation IV/4.

There was a discussion on Draft Recommendation E and some revision was suggested. This recommendation finally became Draft Recommendation IV/7. It was further suggested that a working group bet set up to keep the nomenclature under continual review and a recommendation to this effect (which became Draft Recommendation IV/6) was formulated. The suggested membership of the working group was Professor Helliwell (*chairman*), Messrs. Dinger, Gallet, Horner, Kimpara, Morgan, Pushkov, Rivault, Storey and Wait.

The Chairman reported that the following names were being proposed for the offices of Commission IV for the next Session :

President : Professor R. A. Helliwell.

Vice-President : Mr. F. H. Dickson.

Secretaries : Messrs. F. Horner and G. Foldès.

He explained that the intention was to replace secretaries about every two sessions and the present suggestions were designed to avoid changing both secretaries at the same time.

A vote of thanks was proposed to the retiring President of Commission IV, Mr. J. A. Ratcliffe.

Final Meeting, 9.00 a.m. on Sept. 4, 1957

Approval of Final Recommendations

The proposed symposium was discussed in detail. Emphasis was laid on the importance of the symposium being a working meeting between experts with a minimum of social functions. It could, if approved, be organized by an ad hoc U.R.S.I. Committee.

The draft recommendations were approved with some modification of the wording and the addition of brief titles indicating the subject matter.

A vote of thanks was proposed to the retiring secretary, Mr. Rivault, who had been in office for eleven years.

Chairman's Final Report on Commission IV

Commission IV, which is concerned with Radio Noise of Terrestrial Origin, has dealt with the following subjects :

(1) *The relation between the characteristics of the source and the wave-form of the received atmospheric*

Direct photography of lightning flashes has been used to relate the light emitted to the electric field changes. The field changes near the flash have been investigated, with particular attention to their variation with distance near the source. Radio noise from tornados and snowstorms has been investigated.

(2) *The use of atmospheric waveforms to investigate phenomena of propagation*

The working party appointed at the last General Assembly reported that it had found considerable agreement between deductions made from the same records by different sets of workers. There is need for more measurements on one and the same atmospheric at different distances, and it is recommended (recommendation 5) that where workers have voluntarily associated themselves into groups for this purpose, U.R.S.I. should facilitate their work by providing means for exchanging data and for joint consultation.

(3) *Measurement and description of the characteristics of received atmospheric radio noise*

The working party appointed at the last General Assembly reported that there was considerable agreement, between different groups of workers, about the characteristics of the noise received at different radio frequencies. It is recommended (recommendation 1) that part of their report should be sent in answer to the

question posed by C.C.I.R., and that the report should be expanded to form an U.R.S.I. special report on the measurement of the characteristics of atmospheric radio noise and their relation to radio interference (recommendation 2).

(4) *Plans for the I.G.Y.*

The plans for work in different countries during the I.G.Y. were reviewed. It was recommended (recommendation 4) that those astronomical observatories where routine records of atmospherics are made for purposes of flare warning should be asked to make their results available to radio workers who study the propagation of atmospherics.

(5) *Whistlers and V.L.F. radio noise of terrestrial origin*

At a meeting of the Commission and at a joint meeting with Commissions III and V new results concerning V.L.F. radio noises were reported. It appeared that man-made signals could travel in the « whistler mode ». Theories were advanced in explanation of some of the V.L.F. noises other than whistlers. A working party was set up (recommendation 6) to review the terminology of V.L.F. radio noises, and a provisional terminology was recommended (recommendation 7). In view of the wide interest by members of U.R.S.I. in the study of V.L.F. radio noises it was recommended (recommendation 3) that a symposium on the subject should be held, under the auspices of U.R.S.I., in 1959.

Recommendations

RECOMMENDATION N° 1

Measurement of Atmospheric Noise

U.R.S.I. Commission IV recommends that the following comments on the measurement of atmospheric noise be communicated to the C.C.I.R.

« U.R.S.I. has considered the C.C.I.R. question « What are the most easily measured characteristics of terrestrial radio noise from which the interference to different types of communication system can be determined » and has also considered C.C.I.R. Study Programme n° 96 dealing with the measurement of atmospheric radio noise. The following comments on these topics are offered to the C.C.I.R.

» Considerable progress has been made during the last few years in the measurement and description of the amplitude characteristics of atmospheric noise. Although time characteristics are also required for a complete statistical description of the noise, useful relationships have been found between the amplitude characteristics alone and the interference caused by the noise to many types of radio service.

» There is general agreement on what amplitude characteristics should be measured, and members of U.R.S.I. are being encouraged to study these characteristics at many more locations, in accordance with the recommandations contained in the Annex. »

RECOMMENDATION N° 2

U.R.S.I. Special Report on Atmospheric Noise

Commission IV recommends that a working group be set up under the Chairman of Commission IV to prepare an U.R.S.I. special report on the measurement of the characteristics of atmos-

pheric noise and their relation to radio interference. This report should be based on the material collected to formulate a reply to C.C.I.R. questions.

Recommendation n° 3

Symposium on Naturally-occurring VLF phenomena

Considering the wide current interest by members of U.R.S.I. Commissions III, IV and V in the study of whistling atmospherics and related types of very low frequency atmospheric noise, Commission IV recommends that consideration be given to the possibility of arranging a symposium on this subject before the XIIIth General Assembly.

Recommendation n° 4

Collection of Atmospheric Noise Data from Astronomical Observatories

Commission IV recommends that a communication be addressed to the International Astronomical Union, expressing the belief that measurements of atmospheric radio noise are being made at many astronomical observatories throughout a large part of each day, and requesting that the results of any such measurements be made available to radio workers. The communication should further suggest that there should be consultation between the IAU and U.R.S.I. to ensure that the measurements are made in as useful and uniform a manner as possible for radio as well as for astronomical applications.

Recommendation n° 5

Cooperative Measurements of the Waveforms of Atmospherics

Commission IV recommends that where groups of workers have coordinated their work on the recording of waveforms of atmospherics with the object of showing their variations from place to place, and there such workers desire to publish a joint account of their combined work, U.R.S.I. should facilitate this work by providing means for exchanging data and for joint consultation.

RECOMMENDATION N° 6

Working Group on Terminology relating to VLF Noise Phenomena

Commission IV recommends that a working group be set up under the Chairman of Commission IV to review continually the terminology used in the description of whistlers and related phenomena, and to make further recommendations on this topic to the XIIIthe General Assembly.

RECOMMENDATION N° 7

Provisional Terminology relating to VLF Noise Phenomena

Until the Working Group set up under Recommendation 6 has reported, Commission IV recommends that the following terminology be adopted tentatively in work on whistlers and related phenomena.

ATMOSPHERICS : Natural electrical disturbances originating in the earth's atmosphere. Atmospherics may be subdivided into the following types :

A. SPHERICS : Atmospherics which originate in, and are propagated through, the space between the earth and the ionosphere.

B. WHISTLERS : Atmospherics which originate in lightning discharges and which are propagated through the ionosphere along dispersive paths.

C. VLF EMISSIONS : Atmospherics which are *not* produced by lightning. They are usually associated with magnetic disturbance and have often been referred to loosely by the term « dawn chorus ». The following sub-groups are recognized :

1. *VLF Hiss* : A relatively steady VLF emission generally exhibiting a frequency-dependent amplitude spectrum. Its spectrum and intensity may change slowly (period of several seconds or more) with time.

2. *Discrete events* : Well-defined VLF emissions having durations of the order of a few tenths to several seconds. A definite and repeatable frequency-time relation in often observed.

3. *Chorus* : A series of discrete VLF emissions, often overlapping, with time separations of less than one second.

Annex to Recommendation nº 1

Prepared by : W. Q. Crichlow, *Chairman*
G. Foldes, F. J. Hewitt, F. Horner, H. Shinkawa
and A. W. Sullivan

1. — Measurements

It would be highly desirable to obtain detailed statistical information on the amplitude-probability distribution of the instantaneous envelope voltage, the various time functions, and the direction of arrival of the noise at many locations throughout the world. However, since continuous detailed measurements of this type at all frequencies and at a large number of stations become prohibitive because of the complexity of the equipment involved and the large number of personnel necessary to carry out the observations, it is recommended that these complete studies of the detailed noise characteristics be confined to a few selected locations with continuous measurements of one or more simple parameters at a large number of stations.

The amplitude-probability distribution has been measured at a number of locations and three proposals have been made for the mathematical representation of the distribution. The simplest of these is the log-normal distribution, which can be completely represented by means of two parameters, the average logarithm and the standard deviation, expressed in logarithmic units. By simple mathematical relationships, it can also be expressed in terms of the average power and the average envelope voltage.

Another representation is of the form :

$$Q(v) = \left\{ 1 + \left(\frac{2v}{\bar{v}} \right)^q \right\} - 1$$

where Q (v) is the fraction of the time for which the envelope exceeds different voltages v,$\bar{v}$ is the average envelope voltage and q is a constant determined experimentally. This expression can be evaluated in terms of three measured parameters.

The third form is represented by the following expressions :

$$Q(v) = e^{-y^2}$$

$$v = a_1 y + a_2 y^{\frac{b+1}{2}} + a_3 y^b$$

$$b = 0.6 \left[20 \log_{10} \frac{v_{\text{rms}}}{\bar{v}} \right]$$

The constants in these expressions can be evaluated by means of three measured parameters such as the average power, the average envelope voltage, and the average logarithm of the envelope voltage. Although this expression is more complex and requires the measurement of one moment more than the log-normal distribution, it has the advantage of being able to represent the complete amplitude time distribution of the noise over a much wider range of probabilities.

Since all three of these representations of the amplitude time distribution can be described by means of measured moments, it is recommended that measurements be made at as many locations as possible of the average power, the average envelope voltage, and the average logarithm of the envelope voltage. If only one parameter is to be measured, priority should be established in the order given. The number of parameters actually necessary to describe the true distribution will be determined by the variability of shape that is observed from one place to another and as a function of time and frequency. If a sufficient number of systematic tendencies can be found for the shape of the distribution, then fewer moments will be required to show the variability.

It is recommended that studies be continued of the relationship between the various parameters, such as the ratio of the r.m.s. to the average under all conditions, i. e. as a function of time, frequency, and location. Studies of the influence of band on all of the parameters as well as the statistical distributions are recommended.

It is certain that measurements of some time functions of the noise such as lengths of pulse or of noise bursts will be required for a full description, but it is not present clear which of these should be recommended.

Direct measurement of the moments is preferred instead of measurements of the Thomas type, but it is recommended that the operation of existing Thomas stations be continued until they can be replaced with the recommended measurements.

Although DF measurements are desirable at certain selected locations, it is recommended that omnidirectional antennas be used at most stations, in order to insure uniformity of results.

In making any measurements of noise, it is extremely important

to carefully state all conditions of measurement so that observations by different experimenters can be interrelated.

II. — Techniques

A. — *Probability Distributions*

In making detailed statistical measurements on the instantaneous noise envelope voltage, it is recommended that measurement should be based on counting techniques, for example, using 10 kc/s pulses gated by the noise. These are the most versatile, since counting equipment can readily be adapted to the measurement of a number of parameters, such as the amplitude probability distributions, the distributions of the pulse lengths, and the intervals between the pulses.

The equipment necessary for making such measurements will generally contain the following components :

1. antenna,
2. calibrating signal,
3. calibrated attenuator,
4. receiver,
5. selective circuits of known effective bandwidth,
6. envelope detector,
7. amplitude disciminator,
8. gating circuits,
9. signal generator (usually about 10 kc/s),
10. one or more frequency counters.

The design of the receiver must be such that its recovery time is very short upon overload by high amplitude pulses. Except for this limitation, there are no severe dynamic range or linearity requirements. The receiver noise, of course, must be lower than the level of external noise that is to be measured.

The distributions are obtained by gating the 10 kc/s signal on for the period of time during which the noise level exceeds the threshold of the gating circuits, and by changing the amount of the attenuation at the input of the receiver in known steps. Various lengths of counting time are used at the different threshold levels. In general, 100 seconds is used for values of 5 % and

greater, 200 secondes for values in the range of 0.0005 % to 5 %, and 300 to 1000 seconds for values less than 0.0005 %. In general, a total of about 10 minutes is required to obtain all but the last three low percentage readings, which themselves may take 10 to 20 minutes in order to obtain statistically constant data. The total time required is a function of the type of noise being measured. A longer time is required for noise with a large dynamic range.

B. — *Individual Parameters*

1. *Average Envelope Voltage.* — The basic equipment for measuring the average envelope voltage is as follows :

(*a*) antenna,

(*b*) calibration source (signal generator or noise diode),

(*c*) frequency selective circuits of known effective bandwidth,

(*d*) envelope detector (detector capable of following the peaks of the I.F. cycles at the audio-frequency rate),

(*e*) integrating circuit (usually an RC circuit with a time constant of 100 seconds or more),

(*f*) AGC or variable attenuator circuit (controled by the integrated voltage),

(*g*) recorder circuit (the recorder should indicate the magnitude of the control voltage which is calibrated in terms of the input signal level).

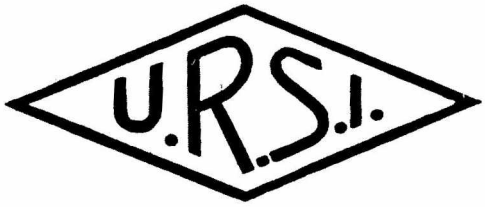
It is essential for the receiver to be linear over the important dynamic range of the noise being observed, for a fixed gain, so that the noise envelope is undistorted at the detector output. This requires an instantaneous dynamic range of 40 db or more. The required dynamic range is a function of the type of noise being measured and the bandwidth of the equipment. The narrower the bandwidth, the smaller the dynamic range. Usually bandwidths the order of 300 cycles to 1000 cycles are used. The gain stability of the equipment must be adequate to insure repeatability of calibrations. The noise figure of the equipment must be as low as possible to minimize contamination of low noise levels.

2. *Average Power.* — The required circuitry for measuring the r.m.s. voltage, or noise power, is similar to that required for average

envelope measurements, except that just prior to detection a square law circuit is used. This circuit can consist of two tubes with the grids in push-pull and the plates in parallel ; thus, producing in the plate circuit a voltage at twice the input frequency and with an amplitude proportional to the square of the input voltage. The amplifier and detector that follows must have a much larger dynamic range in order to handle the squared values without distortion. Using a bandwidth of about 300 c/s, a dynamic range of 80 db or more is required ; however, much smaller bandwidths can be used for the power measurement, since the power is directly proportional to bandwidth regardless of the type of noise. Using a bandwidth the order of 1 c/s, the required dynamic range is reduced to about 40 db or less, since for these bandwidths the noise has the characteristics of thermal noise and approaches a Rayleigh distribution. The time constant used will depend to a certain extent on the bandwidth ; however, a time constant of 500 seconds seems to give adequate smoothing.

3. *Average Logarithm.* — The equipment required for measuring the average logarithm is again very similar to the equipment for average envelope measurements. The principal difference is that a logarithmic amplifier is inserted between the envelope detector and the integrating circuit. A convenient circuit is a triode operating at zero bias and with a high value of grid resistance so that the plate current is an exponential function of the applied grid voltage. With this type of measurement, a time constant of the order of 50 seconds has proven satisfactory. It should be noted that the logarithmic amplifier must be capable of operating at the envelope frequency, i. e. the integration must occur after the logarithmic circuit rather than prior to or within the logarithmic circuit. It should also be noted that the gain control voltage must be obtained after integration rather than before integration.

INTERNATIONAL SCIENTIFIC RADIO UNION



Proceedings of the XIIth General Assembly

held in Boulder, Colorado, U. S. A.
from August 22nd to September 5th, 1957

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On Radioastronomy

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On Radioastronomy

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List of Reports and Papers submitted to the Commission

The asterisk indicates reports published in this part.

N°	Titles and Authors
1	C.C.I.R. findings of interest to U.R.S.I., *U.R.S.I. Inf. Bull.*, **100**, 48-81.
2*	Report from Sub-Commission V*a*, on the continuous 24 hour survey of solar radio emission, A. H. DE VOOGT, Chairman.
14*	Report of the Belgian National Committee, R. COUTREZ, Observatoire de Radio-Astronomie, Humain.
42	A multiphase radio interferometer for locating the sources of solar radio bursts, T. HATANAKA, S. SUZUKI. Tokyo Astronomical Observatory, University of Tokyo.
43	Emission mechanism of polarized radio bursts, T. TAKAKURA, *Ibid.*
44	The position and size of the source of the most intense solar-noise burst on February 23, 1956, at a frequency of 4000 Mc/s, H. TANAKA, T. MAKINUMA, The Research Institute of Atmospherics, Nagoya University.
45	Direct measurements of polarization of the radiation from individual radio spot at a frequency of 4000 Mc/s, Same authors.
64	About one possibility of using small-aperture antennas for estimating the position of local sources of radio waves on the Sun's disk, J. BUDEJICKY, Astronomical Institute of the Czechoslovakian Academy of Sciences.
93	On solar radio emission, V. V. VITKEVITCH.
94	Research on the irregular structure of the ionosphere by means of radio-astronomical methods, V. V. VITKEVITCH, J. L. KOKURIN.
95	Observations of polarized sunspot radiation at a wavelength of 3 cm, D. V. KOROTKOV, N. S. SOBOLEVA.
128*	Report on British work in radio astronomy since 1954, A. C. B. LOVELL.

N°	Titles and Authors
142*	Report of the Swiss National Committee to Commission V, Prof. WALDMEIER.
162*	Report of the Italian National Committee.
168*	Report of the Netherlands National Committee.
173*	Report of the Czechoslovakian National Committee.
177	On the origin of radar echoes associated with auroral activity, J. MEOS, S. OLVING, Research Laboratory of Electronics, Chalmers University of Technology, Gothenburg, Sweden.
178	Observations of radio star scintillation at high latitudes, H. HVATUM, T. ORHAUG, *Ibid.*
179	Continued visual and radar observations of meteors, B. A. LINDBLAD.
187*	Report of the Canadian National Committee.
194*	Report on German Work in Radio-Astronomy.
201*	Report of the Japanese National Committee, Y. HAGIHARA.
217*	Report of the Swedish National Committee, O. E. H. RYDBECK.
225*	Report of the Australian National Committee.
234	Electromagnetic wave reflexion and spare charge wave propagation in electron streams, O. E. H. RYDBECK, Research Laboratory of Electronics, Chalmers University of Technology, Gothenburg.
237*	Report of the French National Committee.
259	Instrumentation techniques in radio astronomy, P. D. STRUM.
260	An X-band switched source comparison radiometer, H. I. EWEN
264	The fading of meteoric radio echoes, A MANNING.
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266	Oblique meteoric echoes from over-dense trails, A. MANNING.
293	On the directional properties of meteor burst propagation, R. F. MLODNOSKY.
294	Radar studies of 15th magnitude meteors, P. B. GALLAGHER, V. R. ESHLEMAN.
295	The initial radius of meteoric ionization trails, A. MANNING.
299*	Report of the U. S. Commission V.
306	Report of the Chairman of the Permanent Committee on Ursigrams.
310*	Report of Sub-Commission Vc.

Sub-Commission Reports

N° 2. — Report from Sub-Commission Va, on the continuous 24 hours survey of solar radio emission

by A. H. DE VOOGT

I. — ACCOUNT ON THE PRESENT SITUATION WITH REGARD TO THE WORLD-WIDE SURVEY OF SOLAR RADIO EMISSION

(*a*) *Observations of total flux and outstanding occurrences.* — The frequencies on which routine measurements of solar radio emission at the present moment are being made by various observatories can be divided into four groups :

2800-3750 Mc/s	Toyokawa, Nera, Ottawa,
460- 600 Mc/s	Ondrejov (Prague), Humain (Belgium), Nera, Boulder.
200 Mc/s	Tokyo, Nera, Harestua (Oslo), Arcetri (Firenze), Cornell, Paramaribo.
169 Mc/s	Humain, Nançay (France), Boulder.

The world-wide survey of solar radio emission is best realized on frequencies near 3000 Mc/s and on 200 Mc/s. In the winter season (northern hemisphere) the survey is not yet complete. In winter there is a gap of some 2 hours between the observing periods of the north American and of the Japanese observatories, whereas the gap between the Japanese and the European observing periods amounts to about one hour. No observatory has been established on one of the islands in the Pacific, for example Hawaii or Tahiti.

Monthly data on solar radio noise were received by the The Hague office from all but one of the above mentioned observatories. These were redistributed to a small number of institutes that

did not make radio noise measurements themselves. Almost all observatories give 3-hourly means of flux values and variability. Only the Toyokawa (3750 Mc/s), Ondrejov (460 Mc/s) and Nera (200 and 545 Mc/s) observatories give hourly means.

Regular observations on other frequencies are being made :

on 9400 Mc/s : by the Research Institute of Atmospherics, Toyokawa, Japan, and by the Heinrich Hertz Institut, Berlin-Adlershof.

on 1500 Mc/s : by the Heinrich Hertz Institut.

(*b*) *Polarization measurements.* — Although in the list « Outstanding Occurrences » of the *Quarterly Bulletin* one column is reserved for polarization data, few information on the polarization of radio events until now is contained by it from the end of 1953. However, this does not mean that observatories that make polarization measurements are lacking. As far as known to me, there are at least four observatories which actually do so : Toyokawa (3750 Mc/s), Tokyo (200 Mc/s), Nera (200 Mc/s), Cornell (200 Mc/s),

I would like to recommend that the results of the polarization measurements will be made available for inclusion in the *Quarterly Bulletin*. If calibration difficulties are still to be solved, a simplified scheme might be used, for example :

R, L (right- or left-handed polarized) O (unpolarized), Ir (irregularly polarized).

(R), (L) (weakly right- of left-handed polarized).

The state of polarization of the enhanced radiation might be indicated in the same way.

(*c*) *Interferometer position determination.* — It is highly desirable that the results of interferometer measurements will be made available. The *Quarterly Bulletin on Solar Activity* seems to be most appropriate to contain these data. However, there has not yet been prepared a simple scheme for the presentation of interferometer measurements. For the present therefore it would be very valuable if the individual observatories would decide to publish their own interferometer measurements at regular intervals. As far as known to me, interferometer measurements are being made at the present moment by the following observatories : Toyokawa (3750 Mc/s), Ottawa (2800 Mc/s), Sydney (1420 Mc/s), Nançay (169 Mc/s), Nera (255 Mc/s), Cornell (200 Mc/s).

It should be realized that we are still very far from having a complete 24-hour interferometer survey. Most interferometers can be used only during a few hours around local noon. The information on changes in position of sources of enhanced radiation and in positions of outbursts therefore will be only fragmentary.

II. — The Classification of solar radio events

Four main systems of classification are in use at the present moment :

1. The old classification scheme by which the types of outstanding occurrences are indicated in the *Quarterly Bulletin on Solar Activity*. The type symbols do not give a detailed specification of the occurrences. This system by now seems to be somewhat old-fashioned.

2. The classification scheme introduced by H. Dodson. This system summarizes the main radio events in a simple and rather complete way. It is used for the type indications in ursigrams.

3. The Cornell classification. This system gives the most detailed and complete description of solar radio events. However, for those who do not have available solar noise records themselves, the wealth of information which is conveyed by the Cornell scheme of classification perhaps is somewhat confusing. This system is being used by the Cornell and Humain observatories.

4. The spectral classification of the C.S.I.R.O. radio observatory (Dapto, near Sydney). This classification gives a concise summary of radio events that occur over an extended range of frequencies. It is meant for those observatories which have a radio spectrograph at their disposal.

It is doubtful whether any classification scheme can be devised which in all respects is quite satisfactory. It should not be too simple, hardly conveying any information at all ; nor should it be too much elaborated, at the cost of its clarity or simplicity. For ursigrams the Dodson scheme is quite useful. For final publication it does not seem necessary to use a system which is much more elaborate.

A complete list of radio events contains a confusing amount of data. Still, the information on a particular event that is

contained in such a list conveys only a vague notion of what happened. Therefore it would be valuable if some of the more important or rare radio events were listed separately and if they were briefly commented upon. This might be especially important to those who do not make radio noise observations themselves.

N° 310. — Report of the Sub-Commission Vc for the period 1954-1957

1. The Sub-Commission is glad to record that the number of observatories making regular records of solar radio emissions has increased since 1954. There is now almost continuous observation of the radiation at 200 Mc/s. In addition, radiospectrographs for observing solar radio disturbances are now installed and in operation at the present time, at the following observatories :

C.S.I.R.O. Division of Radio Physics, Field Station Dapto, near Sydney, Australia ; Harvard Radio Astronomy Station, Fort Davis, Texas, U. S. A. ; The observatory, University of Michigan, Ann Arbor, Michigan, U. S. A. Installations for similar work are under construction and should shortly be in operation at the following observatories :

Tokyo Astronomical Observatory, Mitaka, near Tokyo, Japan.
Fraunhofer Institut, Freiburg im Breisgau, Germany.
Observatoire de Meudon, Meudon (Seine-et-Oise) France.

In addition, interferometric observations to locate the radio emitting centers on the sun are now in operation at :

Nagoya University, Toyokawa, Japan at 3750 Mc/s.
National Research Council, Ottawa Canada at 2800 Mc/s.
Radio-Physics Laboratory, Sydney, Australia at 1420 Mc/s.
Carnegie Institute, Washington, D. C., U. S. A. at 300 Mc/s.
Observing Station, Nederhorst den Berg Radio, Holland at 200 Mc/s.
Cornell University, Ithaca, New York, U. S. A. at 200 Mc/s.
Station de Recherches de Nançay (Cher) France at 169 Mc/s.

2. A daily index I of the Solar radio emissions has been prepared at Ottawa and regularly published for each Greenwich day since 1947, in the I.A.U. *Quarterly Bulletin on Solar Activity*. This

index is simply the flux density about 16.00 UT of 10 cm radiation, frequency 3000 Mc/s, expressed in units of 10^{-22} watts per square meter per cycle per second.

3. Daily observations of approximately 10 cm solar radio waves are also made at Toyokawa (8 cm), as well as at Ottawa (10 cm). In view of the comparative steadiness of such radiation, this observing programm seems adequate.

4. In our 1956 report it was stated that the observatories of Meudon and Sydney would collaborate to prepare proposals for a 3-hourly index of the intensity of noise storms. Such proposals are given in the following section.

5. It is now recommended that the solar radio emission during each 3-hourly period of the Greenwich day shall be characterized by 3 indices with symbols, F, V and B given in this order. Each of these indices should range from 0 to 3.

All these indices will be based on the radiation at 200 Mc/s, which, as above noted, is now almost continuously observed.

(*a*) The index F clarifies the median flux density φ and the proposed limits for each class number are as follows : (the unit for flux is here taken to be 10^{-22} $W.m^{-2}.(c/s)^{-1}$).

F	φ
0	<10
1	10-20
2	20-35
3	>35

(*b*) The index V clarifies the variability of the flux above its smoothed minimum course. The variability could be reckoned on the basis of the number n and the height h of successive maxima or peaks observed during each 3-hour period. From the record, a weighted number n' of peaks per minute is estimated. This estimate should approximate to that calculated from the formula :

$$n' = \frac{1}{60} \sum_{1}^{h} \left| \log_{10} \left(\frac{h}{F} \right) \right|$$

The class number V is then assigned on the following basis :

V	n'
0	<1
1	1-2.5
2	2.5-4
3	>4

(*c*) The index B characterises the energy of the outstanding bursts above the general flux, whether or not a noise storm is in progress. The burst activity can be reckoned on the basis of the integrated energy of the burst, namely the area of the flux density-time record above the general flux. This integrated energy is to be measured or estimated and the class number B is then assigned on the following basis. The energy is reckoned in units 6×10^{-20} joule.m^{-2}.$(c/s)^{-1}$.

B	energy
0	<3
1	3-30
2	30-150
3	>150

6. It is recognized that such trios of indices based only on one wave length must give an improper representation of the activity of solar radio emission, but for the present and in particular for the period of the I.G.Y., the course proposed seems the most practicable way that can be chosen.

7. Such 200 Mc/s indices may be supplied by more than one observatory for the same 3-hour period and may differ. It is recommended that in such cases it be left to the discretion of the editor of this section of the *Quarterly Bulletin* to assign the values of the indices, and also, if possible, to assign indices for periods in which no such indices are supplied by the observatories. In doing so, we will naturally take into account other available informations, namely records on frequencies approximative to 200 Mc/s.

8. The 10 cm daily index I will give an approximate idea of the solar radio emissions from atmospheric levels, and the 200 Mc/s FVB indices will similarly indicate coronal activity.

9. Daily indices of such coronal activity can be formed in averaging or summing the eight 3-hour indices, and such averages should be given in the *Quarterly Bulletin*.

Collaboration with the C. C. I. R.

The Plenary Assembly of the C.C.I.R. held in Warsaw in 1956 asked the collaboration of U.R.S.I. for Recommendation n° 173 (Protection of frequencies used for radio-astronomical measurements) pertaining to the field of Commission V. The full text of this recommendation was published in *Information Bulletin* n° 100 (November-December, 1957).

National Committee Reports

Australia

N° 225. — Report of the National Committee to Commission V

Introduction.
1. Solar Radio Waves.
2. Cosmic Radio Waves :
    2.1. Hydrogen line radiation.
    2.2. Continuous spectrum.
3. Planetary Radio Waves.
4. Meteors.
5. Ionospheric Effects on Radio Astronomy.
6. Magneto Hydrodynamics.
7. Technical.

Introduction

This report outlines research in radio astronomy carried out in Australia since the 1954 General Assembly.

In radio astronomy generally the phase of preliminary discovery is giving place to one of systematic studies, frequently involving increasingly elaborate equipment. In Australia this has been exemplified in the development and use of the Mills Cross for cosmic metre-wavelength studies. Models are in use at frequencies of 19 and 85 Mc/s which have pencil beams of diameter 14° and 0°8 respectively. These directivities are much in excess of those of any other equipement operating in this frequency range, and the results, in addition to giving a wealth of new information, cast serious doubts on the validity of certain older surveys. But even these directivities are insufficient to show detail on the surface of the sun, and an equipment is under construction which is designed to scan the sun, television-wise, with a pencil beam

3 minutes of arc in diameter. Using contrasting techniques of elegant simplicity the low frequency limit of observations of cosmic radio waves has been lowered from about 10 to about 1 Mc/s, by observations at a place and time when the critical frequency of the ionosphere was very low.

The main centre in Australia of research in radio astronomy continues to be the C.S.I.R.O. Radiophysics Laboratory in Sydney. It has carried out research on solar and cosmic radio waves, including hydrogen line radiation, on related ionospheric effects and on radio waves from Jupiter. Work on meteors is carried out at the University of Adelaide, and the low frequency work mentioned above is joint American-Australian work, carried out at Hobart by Grote Reber and G. R. Ellis.

1. — Solar radio waves

Routine observations of dynamic spectra of bursts have been made since 1952, and are now published in the *I.A.U. Quarterly Bulletin on Solar Activity*. It has been found that type III bursts, those showing a rapid frequency drift, have an association with flares. Groups of these bursts frequently precede a type II burst (slow frequency drift) at the time of a large flare. It has been suggested that both these bursts are indicators of rapidly moving disturbances in the solar atmosphere, of which the type III may be associated with the ejection of cosmic rays and type II with geomagnetic storm particles (57, 61). Type III bursts are also found to have some association with very small flares. In an attempt to follow up these moving disturbance hypotheses, equipment is being developed to obtain simultaneous information on the spectrum, polarization and apparent position on the sun of bursts of solar noise.

Observation with the Christiansen multi-element interferometer on a frequency of 1400 Mc/s were completed (9). These gave the quiet-sun brightness distribution near sunspot minimum. An analysis of this work has been undertaken in order to determine the effect of the slope and finite width of the aerial beam on the derived brightness distribution. It has been shown that the two-dimensional brightness distribution derived from variously oriented strip scans is the same as would be obtained with a circular

beam having a power response elated to that of the strip instrument (50). The effect of the finite beam width on the brightness distribution over the solar disk will be to produce an apparent extension of the disk, and to degrade and shift the brightness peaks which may appear close to the limb. When these factors are taken into account it is found that the 1400 Mc/s observations during the years 1952-1953 are consistent with coronal densities tabulated by van de Hulst for the time of sunspot minimum.

The 1400 Mc/s results have been examined to determine the characteristics of the bright spots which give rise to the slowly variable component. These spots are very closely connected with bright hydrogen plages, with Babcock's magnetic-field regions, and with bright coronal regions. A typical one is four minutes of arc across and has a brightness temperature of 10^6 °K. It was feasible to use a method employing a knife-edge beam to study the sun at sunspot minimum where the pattern on the disk was usually relatively simple, but with the coming of sunspot maximum the expected patterns will be too complex. In an attempt to meet the difficulty a new instrument has been designed which will scan the sun with a pencil beam, television-wise, and so produce radio pictures of the sun or radioheliograms.

Observations were made (51) with the original 32-aerial system adapted for use at 500 Mc/s in an attempt to confirm the existence of limb-brightening at this frequency. Earlier observations had led to the conclusion that, contrary to theoretical expectation, it was absent. The results confirmed the existence of limb-brightening.

In June 1956 an occultation of the Crab Nebula by the corona of the sun was observed (48) by means of a pencil beam system; the 85 Mc/s Mills Cross. It has previously been shown by Cambridge workers that the influence of the corona was appreciable out to several solar radii and from interferometer observations they had inferred a certain pattern of forward scatter and a consequent structure in the corona.

The 1956 pencil beam observations confirmed the wide extent of the effect but did not conform with details of the extrapolated pattern of forward scatter. This could be due to a change with sunspot cycle, but further observations combining the pencil beam and interferometer techniques are desirable.

Routine single frequency observations at various frequencies have been taken since 1954. The present ones are 200, 600 and 1400 Mc/s.

2. — Cosmic radio waves

2.1. — 1420 *Mc/s line radiation*

Observations of the 1420 Mc/s line radiation have continued by means of a 36-foot paraboloid and a four-channel receiver in which fluctuations in gain are suppressed by continuously opposing the signal in each channel with that in a channel outside the frequency band of the line. A new 48-channel receiver employing a switching technique is under development.

A study was made of prior observations of the hydrogen line radiation from the Clouds of Magellan, the mass of hydrogen was derived and each cloud shown to be rotating (17). From the rotational characteristics the total masses were estimated (18).

An extensive survey has been made of the part of the Milky Way visible from Sydney (7). The primary reduction of results is complete. This southern survey complements the Leiden work for the northern part. Multiarm spiral structure is evident, with the arms trailing, as was found also in the Leiden observations.

Near the sun, the neutral hydrogen provides about 15 per cent of the total density, but in the nuclear regions the proportion of hydrogen by mass is quite low. Integrating over the whole Galaxy, the hydrogen amounts to about 2 per cent of the total mass.

The gas is found to be concentrated in a remarkably thin disk with a width between half-density points of about 250 parsecs. This disk is also remarkably flat over the main part of the Galaxy, and hydrogen line observations should provide the best evidence for the current revision of the galactic plane by the International Astronomical Union. A provisional solution has been obtained for the « principal plane » of the Galaxy.

In the outer regions, the gas shows systematic deviations from flatness at the edges near to and remote from the Clouds of Magellan (20). On the near side the disk is bent towards the clouds ; on the far side, away from them. This distortion suggests a tidal effect, but the magnitude appears much greater than that

due to gravity. It suggests the existence of some other force, perhaps viscous, perhaps electromagnetic. A more detailed study of the results should provide much information on the structure and velocity pattern in the galaxy. For example, observed profiles in the galactic plane at longitudes equally distant from the galactic centre are not symmetrical. This is thought to be due to structural asymmetry rather than deviations from circular orbits.

2.2. — *The Continuum*

Equipment. — The two Mills Crosses on frequencies of 85 and 19 Mc/s respectively are used for surveying the sky south of declination +10°, and give information on both the discrete sources and the background. The 85 Mc/s Cross was constructed in 1954 ; it was used for observations of selected objects until October 1955, and a survey of the sky has just been completed, although the reduction of observations is scarcely half done. The 19 Mc/s Cross was completed in mid-1956 and observations are at an early stage. A survey of the sky on 600 Mc/s was made using a 36-foot diameter paraboloid and a conventional, switched receiver, and observations were made of the angular size of discrete sources on 100 Mc/s, using a radio-link interferometer, similar to that previously described, with a spacing of several kilometres.

The very low frequency observations extending the spectrum of cosmic radio waves down to 1 Mc/s were carried out at Hobart, a place where ionospheric critical frequencies are particularly low. Results of observations are described below, novel technical points in Section 7.

85 *Mc/s Cross Observations.* — With an instrument having the sensitivity and resolution (0°8) of the 85 Mc/s Cross it is possible to recognize a reasonably large number of objects and to study the radio emission from selected classes of astronomical objects. Classes which have been studied include :

(i) *Normal bright galaxies* (23). — (Nine detected and Magellanic Clouds studied in detail ; rough ratio of radio emission to light determined for the various galactic types ; S*b* and S*c* strongest emitters, E undetectable).

(ii) *A possible class of morphologically similar abnormal galaxies* including NGC 5128, a known radio source, NGC 1316 and NGC 1947. It was confirmed that NGC 1316 was a radio source and it was shown that NGC 1947 was not ; the existence of a homogeneous class was therefore disproved (22).

(iii) *Bright emission nebulae* (25). — (Seven detected, in emission or absorption, according to circumstances ; emission appears thermal, free-free transitions).

(iv) *Novae and supernovae* (24). — (Kepler's star definitely identified, novae undetectable).

(v) *Globular clusters* (23). — (Undetectable, very poor emitters).

(vi) *Clusters of galaxies* (28). — (Of five bright southern clusters, four had associated radio sources).

Various external galaxies suggested as potential radio sources on the basis of optical pecularities were studied, but none proved to be an intense radio source (31).

The observations of the main survey are now complete, and cover the sky between declinations $+10^{o}$ and -80^{o}. A catalogue of discrete sources is being prepared as well as detailed isophotes near the galactic plane, and smoothed isophotes over the whole area. The source catalogue is complete in a sample area of the sky of about one steradian, which is common to the Cambridge survey on the adjacent frequency 81.5 Mc/s. The catalogues, which include 383 Sydney and 227 Cambridge sources, disagree grossly. Reasons have been advanced to show that the Sydney results, which have higher angular resolution, are more likely to be correct (27).

The Cambridge results show an unexpectedly large number of faint sources and interesting cosmological conclusions have been drawn. The Sydney results do not show this excess. It is possible that a small excess exists but it lies within the observational uncertainty. The analysis is complicated by clustering effects.

The preparation of isophotes over the sky is at an early stage. Sample sections over the Milky Way at various longitudes have been examined. They confirm the division of the radiation from our galaxy into two principal components, as proposed by

Shklovsky; a quasi-spherical component with a half-width of the order of 60°, and a disk component, half-width about 3° (23). Detailed isophotes have been prepared for a 10° square region about the galactic centre (26). These show an elongated peak near the centre, with a slight depression at the place where the intense source is observed on high frequencies. This implies a complex structure involving thermal and non-thermal sources, and explains the disagreement of earlier observers. Isophotes have also been drawn around sources of adequate angular size, including NGC 5128 (23), 1316, and Puppis A.

Occultations by the moon of IC 443, the Crab Nebula, and Kepler's nova have been observed.

19 *Mc/s Cross Observation.* — Preliminary observations with the Mills Cross with its 1°4 pencil beam include (46) sample sweeps across the Milky Way and a detailed survey of a 10° square about the galactic centre. These show generally high brightness temperatures of the order of 10^5 °K, with two ridges, one running each side of the galactic equator. The trough between the ridges is very irregular. It is clear that the trough is due to absorption in irregularly distributed H II regions near the galactic plane. At this frequency the absorption is very high, and its presence appears to be the most sensitive indicator of H II regions yet available in astronomy. The 19 Mc/s observations studied in conjunction with similar observations at higher frequencies, where absorption is less, promise a wealth of information in the distribution of ionized hydrogen in the nearer parts of the Galaxy.

600 *Mc/s Survey.* — A survey of the sky between declinations +50° and −90° has been made (38), using a 36-foot diameter paraboloid, having a beamwidth of 3°3. Forty-nine discrete sources were catalogued (37), largely in the vicinity of the Milky Way, and detailed isophotes were drawn in an area extending up to about 45° from the galactic equator.

101 *Mc/s source size observations.* — Observations of angular size of a moderately large number of sources were made using a radio-link interferometer with 25-ft. square aerials spaced at 90 and 1000 wavelengths in an east-west line. The ratio of fringe amplitudes was interpreted in terms of an assumed model

of brightness distribution and the equivalent angular size was deduced. Seventy-five of the most intense sources were observed, but confusion effects would reduce the number of reliable determinations to about half this number. The most common equivalent size observed was 2 minutes of arc ; the smallest about 0.5 minute.

Observations below 10 *Mc/s.* — During the last few years observations at the low frequency end of the spectrum of cosmic radio waves have become specially interesting because of the hypothesis that « synchrotron radiation » may be an important emission mechanism. On this hypothesis the spectrum should have a maximum at a frequency which depends on the electron energies and magnetic fields in the interstellar gas.

Observations have been made at Hobart (11, 12, 14, 40) of both the general background and discrete sources in the range 10 to 1 Mc/s. The background has been measured down to 2 Mc/s and lower limits determined down to 0.9 Mc/s. The spectrum expressed in brightness units (Watts $m^{-2}(c/s)^{-1}$Steradian^{-1}) increases with decreasing frequency down to about 10 Mc/s. Below this it flattens and may decline.

Observations of discrete sources have been made at 18 and 10 Mc/s using a phase-switched interferometer (13). Six sources were observed and showed considerable differences in spectra over this frequency interval. Two showed a marked decrease in flux density at the lower frequency. It is probable that the observations are markedly influenced in certain cases by absorption in ionized hydrogen between us and the source.

A discrete source showing anomalous fluctuations. — The discrete source Hydra A (I.A.U. 09S1A) was observed (47) using the 100 Mc/s sea-interferometer to show more pronounced fluctuations than the scintillations of other, apparently similarly situated, radio sources. Observations on the east-west arm of the 85 Mc/s Mills Cross confirmed this anomalous behaviour. Angular size measurements (8) on 101 Mc/s also showed apparent size fluctuations, not correlated with the intensity fluctuations, in excess of its neighbours. The radio source is tentatively identified with a faint galaxy, and if so the actual emission from the source could scarcely show variations of seconds and minutes duration.

The explanation of the observed anomalous fluctuations is not known ; that the fluctuations arise close to the earth is suggested by an observation made at Cambridge, which showed that the fluctuations, there, of this source did not differ from others.

3. — Planetary radio waves

Following the discovery in America of radio emission from Jupiter, Radiophysics Laboratory records, covering many years and several frequencies, were searched for signs of Jupiter radiation. This radiation was found only on records taken at 18.3 Mc/s ; there was no sign of Jupiter at higher frequencies.

A detailed examination of the 18.3 Mc/s Australian records showed (45) that in 1950-51 the radiation came, not from the planet as a whole, but from a limited area of its surface. From the rotation period and longitude the active region was identified with a region in the South Temperate Belt which had also been noted as disturbed in visual observations.

Towards the end of 1955, equipment was set up to make further observations of Jupiter emission. The earlier result, namely the comparatively small area of the sources of the radiation, has been confirmed, but no simple identification of the 1955-56 radio sources with optical features has been found possible. Three sources were active at 19.6 Mc/s, but only the principal one of these radiated appreciably at 27 Mc/s. The new information concerning the Jupiter radio emission coming from this work may be summarised as follows : — the terrestrial ionosphere has a considerable effect on the short-term variations in the received radiation, records at the same frequency appearing different at two stations 25 km apart ; the shortest durations of bursts recorded were of the order of 0.5 sec., although the equipment would respond to bursts as short as 0.01 sec ; the intensity and frequency of occurrence at 19.6 Mc/s was about 2 or 3 times as great as at 14 or 27 Mc/s and in general there was no correlation between the short duration bursts at 19.6 and 27 Mc/s ; the angular spread of the radiation was less at 27 than at 29.6 Mc/s, the axes of the « beams » being displaced ; the one suitable record showed strong circular polarization.

4. — Meteors

Routine monitoring of meteor activity at Adelaide, which commenced in June 1952, continued with the 27 Mc/s cw wide-aperture system until September 1956, and was resumed in December 1956 with the 67 Mc/s radar narrow-aperture system (53, 54, 55). All known meteor showers visible from Adelaide have been detected, and rates and radiant co-ordinates measured, with the exception of the night-time Taurids, from which weak activity only would be expected. In addition, two new night-time showers have been discovered ; the Puppids, a weak shower near declination —40°, active on Dec. 5-7, and a strong shower (possibly periodic) near declination —55°, active on December 5-6 and detected for the first time in 1956. The distribution over the celestial sphere of the radiants of sporadic meteors brighter than $M_r = 7$ has been examined, using both the meteor counts and the directions of reflection points for individual meteors. There is a pronounced concentration to the plane of the ecliptic, with a preponderance of meteors moving in direct short-period orbits of low inclination. The density of sporadic meteors from $\theta = 120°$ to $\theta = 300°$ exceeds by some 50 per cent the density over the remainder of the earth's orbit, in agreement with some other telescopic and visual surveys.

5. — Ionospheric effects in radio astronomy

Scintillations. — Writers in the northern hemisphere have consistently attributed radio star scintillations to irregularities in the F_2 region. Australian workers have suspected also a sporadic E effect. Recent work (58, 59) has shown for scintillations of the radio star Cygnus A, observed at Sydney at angles of elevation around 15°, a clear-cut correlation with both ionospheric regions. It has been established that night-time scintillations (observed during the winter months) are correlated with F_2 irregularities, and day-time scintillations (observed during the summer months) are correlated with sporadic E.

Cosmic Radio Twilight. — Low frequency cosmic noise is cut-off from the earth by the ionosphere when the critical frequency is greater than the operating frequency. But it has been shown

that the effect is not abrupt, as the overhead critical frequency increases through the operating frequency. There is instead a sort of « twilight », due to a combination of several effects ; to the gradual diminution of the area about the zenith where energy can penetrate and to the propagation between the ionosphere and the ground of energy penetrating the ionosphere at some distant place where the critical frequency is adequately low.

Whistlers. — See Commission III report on theoretical prediction of « Nose Whistlers ».

Meteor Winds. — See Commission III report.

6. — Magneto-hydrodynamics

An investigation was undertaken of the various types of disturbance (or waves) in ionized gas in a magnetic field (32, 33). It was established that only four such wave types could exist (34), and the properties, including polarization and rates of absorption of the three hydromagnetic waves, were investigated (35). Some non-linear properties of electric space-charge waves were examined. A long outstanding theory of the spontaneous growth of electric space-charge waves and another theory, of the growth of radio waves in the solar atmosphere, have been criticized (36, *a*, *b*, *c*).

It is known that solar atmospheric heating, flares and other effects are closely associated with solar radio noise. The origin of these effects in terms of hydromagnetic waves has been investigated and a theory of heating developed (39). A theory of flares has reached a preliminary stage of development.

7. — Technical development

7.1. — *Aerials in general*

The fundamental limitations which aerials impose on the ability to delineate fine detail in one-dimensional brightness distributions have been studied. Methods proposed for restoring fine detail have been examined and it has been shown (1) that although some sharpening of the data is sometimes possible, detail finer than a certain limit is irretrievably lost. The study has been extended to two dimensional distributions (5, 6) with particular emphasis on the problem of strip integration (4) ; the

implications of the limit of resolution have been investigated and a number of short methods (2, 3) developed for handling data and effecting the sharpening of data. A method has been proposed (5, 6) for obtaining two-dimensional brightness distributions using a pair of simple interferometers with crossed axes.

7.2. — *Giant radio telescope*

For solar and low-frequency cosmic work, where ample signal level is available, a high resolution can be obtained with specialized devices, e. g. the Mills Cross, but, for hydrogen line work or high-frequency continuum observations, it is necessary to have a large collecting area.

The construction is planned of a steerable paraboloid with an aperture of two or three hundred feet. The present status of this project is that a design study by a London firm of consulting engineers is nearing completion. Meanwhile, likely sites in regions of low noise-level are being investigated.

An alternative form of radio-telescope using a fixed hemispherical reflector in which the beam is steered by moving the feed has been devised (15). Spherical aberration is suppressed through the use of an appropriately shaped secondary mirror which is an integral part of the feed.

7.3. — *Mills Cross at* 85.5 *and at* 19.7 *Mc/s*

General. — Several years ago the analysis of cosmic noise data showed that its distribution across the sky was very complex. This suggested that pencil-beam aerials with high resolving power were required if significant advances were to be made. The problem of obtaining high resolution at metre wavelengths was solved by the development of the Mills-Cross aerial described in the 1954 U.R.S.I. report. This instrument, which consists of a cruciform arrangement of two 1500 ft. arrays of dipoles, has now been in operation since July 1954. It operates at a frequency of 85.5 Mc/s and has a beamwidth to half-power of 50′ of arc. The sensitivity limit under optimum conditions approaches $2 \times 10^{-26} \mathrm{W.m^{-2}.(c/s)^{-1}}$, at which level the instrument is limited by resolution ; this corresponds to a flux density less than 1/10 000 of the flux density, of the strongest radio source, Cass. A. For survey work, however

a scanning system is used which displays the output on five separate declinations quasi-simultaneously (27). This procedure reduces the sensitivity limit to about 5×10^{-26}W.m^{-2}(c/s)$^{-1}$. A positional accuracy of two or three minutes of arc is attainable on radio sources stronger than 5×10^{-25}W.m^{-2}(c/s)$^{-1}$. The use of the instrument has amply justified its construction ; it is clear that pencil beams instruments of this order of resolving power, or preferably higher, are essential for survey work.

Problems. — With a cross-type radio telescope some special problems arise, principally connected with (*a*) sidelobes and (*b*) absolute temperature measurements.

(*a*) Since the overall directional diagram is the product of the voltage diagrams of the individual arrays, sidelobes can be serious along the fan beams of each array. To minimize this effect the current distribution along each array is severely tapered towards the ends. In perfect adjustment the first sidelobe is 2 per cent, and at angles greater than 3° sidelobes do not exceed 0.7 per cent. In order to achieve and maintain this low level it is essential that the amplitude and particularly the phases of the dipole currents be accurately adjusted, and therefore equipment has been developed for this purpose.

Spurious responses due to adjustment errors are substantial in the meridian plane, since these arise as the result of errors in the dipole currents in the N-S array which are changed in phase every time the beam direction is changed, and rapidly accumulate errors in adjustment. Sidelobes of the order of 1 per cent are common and much higher sidelobes occasionally observed in the meridian plane, but they occur always at the right ascension of the strong source producing them and are easily recognizable. In an E-W direction the sidelobes very rarely exceed 1 per cent, as these arise as the result of adjustment errors in dipoles of the E-W array, which, being fixed, are easily maintained in correct adjustment. Outside the fan beams the sidelobe structure is much superior to that of a conventional aerial with sidelobes very rarely exceeding 0.1 per cent.

(*b*) The measurement of *absolute* sky temperature is difficult with a cross-type aerial, because of difficulties with coupling between arrays or, if dipoles are omitted near the centre of the

arrays to reduce this, because of an increased complexity in the sidelobe response. The most effective procedure has been found to be to reduce coupling to negligible values by removing dipoles from one arm only of the cross, preferably the E-W arm. The temperature derived from the other array (N-S) is then added to that derived from the pencil beam, giving very closely the absolute temperature of the area of sky at which the beam is pointing; any remaining errors which may occur near very bright objects may be largely eliminated by a smoothing procedure.

19.7 *Mc/s Cross.* — To supplement the work of the 85.5 Mc/s cross, a 19.7 Mc/s cross has been constructed. At such low frequencies the sensitivity of the instrument is severely limited by the rapid increase in background sky brightness (for an aerial of given *area* the aerial temperature due to a source varies with frequency as the power 1 or even less steeply). Also interference from transmitting stations and ionospheric effects both become very troublesome. Nevertheless observations at low frequencies are of such importance astronomically that the difficulties and drawbacks must be accepted.

The instrument constructed consists of two arrays of $\lambda/2$ dipoles, each approximately 3,500 ft. in length. The resultant beamwidth, after tapering, is $1^{o}4$ between half response points. The sidelobe pattern has not been established yet by measurement but the performance is probably comparable with the 85.5 Mc/s Cross.

It is found that in the present period of sunspot maximum, the useful observing period is limited by interference from radio transmitters to a few hours each night; consequently it is not feasible to attempt a comprehensive survey of the southern sky to supplement the 85.5 Mc/s survey; instead regions of especial interest are being examined in detail.

Calibration. — The gains of the cross-type aerials have been measured by a new technique. Since the gain changes with the declination of the beam, it is essential to measure it at a number of different declinations. The method consists in measuring the flux densities of a number of comparatively strong sources using a half wave dipole placed $\lambda/4$ above an infinite plane reflector as a standard. Since the resolution and gain of the standard aerial by itself is insufficient for effective observations on any southern

sources, it has been used in an interferometer connection with each array of the cross in turn. Thus on any given source three measurements are made, one with the normal cross, one with an interferometer formed by using the E-W arm of the cross with the standard dipole, and one with an interferometer formed from the N-S arm and the standard dipole. From these three measurements and a calculation of the gain of the standard aerial the flux density of the source under observation and the gains of the N-S and E-W array may be separately derived.

Measurements of this type have been made at 85 Mc/s on five strong « point » sources at different elevation angles.

7.4. — Low frequency recording

At low frequencies, recording of cosmic noise is hindered by the opacity of the ionosphere, and by terrestrial interference, particularly from radio stations and atmospherics. Obstruction due to the ionosphere was reduced by observing at a place, Hobart, and time of low critical frequency. Hobart also has relatively few radio transmitters in its vicinity.

It was found possible to record cosmic noise in the presence of interference from terrestrial atmospherics which had an average level up to 10^4 times greater. The basic idea is that the background level may be observed in the occasional quiet periods, which may be as short as 0.1 seconds, which occur between the atmospherics. In its final form an electronic device equivalent to a peak voltmeter but reaching minimum instead of maximum values was used, in conjunction with a pen recorder. The time constant for increasing signal was about 1 minute ; for decreasing, about 0.02 seconds.

7.5. — *Radio heliograph*

This instrument, which is under development, follows the scheme outlined by W. N. Christiansen at the General Assembly of U.R.S.I. in 1954. It combines the principles of the Christiansen multi-element or grating interferometer which gives a series of knife-edge beams, with that of the Mills Cross.

It consists of two 32-element interferometers arranged in the form of a cross. The signals from the two systems are combined

to give a number of pencil beams at the regions of intersection of the fan beams of the respective systems. The spacing between these pencil beams is sufficiently great to allow only one to fall on the sun at one time. The sun is scanned by one pencil beam by permitting the rotation of the earth to move it across the sun. The next beam is then moved in declination (by phase adjustments to the individual aerials of the north-south arm) so that it scans a strip on the sun adjacent to the first. The whole picture is built up by a repetition of this television scanning process.

The equipment, which is expected to be operating before July 1957, operates on a frequency near 1420 Mc/s. The arms are 1240 feet long. Each consists of 32 paraboloids 18 feet in diameter and equatorially mounted with a simple « following » mechanism. With these dimensions the individual beams are 3′ in diameter and are separated by about 1°. The individual aerials are fed through a branching system of twin-wire transmission lines like the original 32-element interferometer. It differs from this in that the feed system is tapered to reduce sidelobes, by transformation introduced at each junction, and the connection to each branching transmission line is by means of a special non-contacting device which can be slid along to introduce phase changes and steer the beam.

The equipment is notable in that it has a resolution approaching that of the human eye.

7.6. — *Frequency-sweep interferometer*

This instrument is similar in principle to that described by Wild and Roberts (58) for observations of the Cygnus-A radio source. Two aerials with unequal feeders are connected to a frequency-sweep receiver. As the frequency changes the phase difference associated with the unequal paths also changes and so superposes an interference pattern on the spectrum of the source. If the aerials are identical this interference pattern gives information on the direction of arrival ; if mutually perpendicularly polarized, on the polarization of the received radiation.

The directional equipment operates over a frequency range of 40-70 Mc/s. The spectrometer itself covers the range 40-

240 Mc/s. The former utilises rhombic aerials of dimensions 3.3 m × 6.5 m spaced 1 km apart. In typical circumstances this gives fringes of 5 Mc/s separation.

It is expected to be in operation before July, 1957.

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Belgium and Belgian Congo

Nº 14. — Report of the National Committee to Commission V

by R. Coutrez

(*Translation*)

I. — Belgium

In the course of 1954 a radioastronomical observatory was erected at Humain-Rochefort, Belgium (5º20'.8 E, 50º12'.5 N, altitude 295 m) in a site free from interferences located 60 miles from Uccle. This station is operated under the responsability of the Department of Solar Physics and Radioastronomy, Royal Observatory of Belgium. Its equipment mainly consists of :

(*a*) A paraboloid of 6 m aperture with superstable receiver on 169 Mc/s (noise factor 2.2, bandwidth 6.0 Mc/s, time constant at the output less than 0.1 sec), equatorially mounted, with the possibility of converting immediately this equatorial mount into

a parallactic one in order to allow observations of the northern part of the sky ;

b) a paraboloid of 7.5 m aperture with superstable receiver on 600 Mc/s (noise factor 4, bandwidth 6.6. Mc/s, time constant ordinarily used 1 sec) ; parallactic mount with automatic tracking of the sun by means of an analogic computer (accuracy 0°1) ;

c) a polarimeter on 168 Mc/s, using two mutually perpendicular Yagi aerials connected with a phase delay of $\pm 90°$ at a rate of 50 per sec, and synchronous detection, to record left and right circularly polarized and unpolarized components of the solar radiation ; reduced sensitivity in order to obtain a correct record of the shape of the strongest bursts ;

d) twin-wave interferometer on 900 Mc/s with two paraboloids of 3 m aperture, baselength East-West of 86 wavelengths ; this instrument has been used previously to detect solar radio sources at meridian transit, and is now modified into a « swept-lobe » interferometer ; this modification will be completed for IGY ;

e) horizontal broadside array with vertical beam of 20° on 25 Mc/s receiver's noise factor 3, bandwidth 2 kc/s for ionospheric absorption measurements.

f) receiver of atmospherics on 27 kc/s.

A large multielement interferometer is presently under development (base East-West : 850 m, 32 paraboloids equatorially mounted of 4 m aperture ; base North-South : 350 m, 16 paraboloids ; possible frequency 400 Mc/s) but will not be completed before two years.

Work at this station is principally devoted to solar radio observations made in connection with solar optical observations at Uccle (in integrated light and in Hα). Observational data of both types are centralized at Uccle where all facilities are available to reduce and compare them. In addition, the Department is provided with a well equipped radio laboratory for construction, alignment and check of radiometers and associated devices.

A) *Routine observations.* — Solar flux measurements on 169 and 600 Mc/s, polarization measurements on 168 Mc/s.

— Mimeographied reports sent monthly to specialized stations and observatories, since January 1956 without interruption. Till

July 1956, only 169 Mc/s. Since August 1956, 169 and 600 Mc/s. These reports on radio solar data are completing those on optical solar data, made for each solar rotation from March 1940 (sunspots) and from January 1954 (photosphere and chromosphere).

— Reports on solar Activity, published every four months, grouping solar radio and optical data together with related information on radiopropagation and geomagnetism.

— Reports published with more or less delay in the review « Ciel et Terre » of the Belgian Astronomical Society and reprinted annually in the « Communications » of the Royal Observatory. They include statistics and evolution of sunspots, data on flares, prominences, heliographic maps of the chromosphere, three-hourly medians of flux density and variability on 169 and 600 Mc/s, data on outstanding occurrences classified *a*) in the scale used for the *Quarterly Bulletin*, *b*) in a modified Cornell scale.

B) *Occasional observations.* — Prior to the regular use of the swept lobe interferometer on 900 Mc/s the instrument reported in par. I, *d* has been used in 1956 by C. Stockmans as a drift interferometer. Active regions were detected and localized above large sunspots groups. The projected brightness distribution was computed and found in fairly good agreement with the data obtained in Australia on 1420 Mc/s. This study will be resumed with the swept lobe interferometer.

Several members of the Observatory (P. Bougeois, R. Coutrez, E. Pourbaix and J. De Lange) took part in the observations of the solar eclipse of June 30, 1954, on 169 Mc/s ; these observations were made on a base roughly perpendicular to the eclipse track and stretching between the north polar circle and the equator in cooperation with « Ecole Normale Supérieure de Paris » and « IRSAC », Belgian Congo, the northern station (Jokkmokk, Sweden) being operated by Royal Observatory of Belgium. The analysis of three homogeneous eclipse curves obtained at Jokkmokk, Goteborg and Paris was made by R. Coutrez (1956) with a new method implying no special assumption for the determination of the two dimensional brightness distribution. The obtained distribution appears elliptical, without center darkening, and slightly assymetrical in relation with very slightly active regions observed in Hα on June 30, 1954. Comparison was made with

a symmetrical model with centre darkening (from interferometric observation on 1.4 m made at Cambridge), but without good agreement with the observed curves on 1.77 m. On the other hand the probable errors on the coefficients of the brightness distribution function indicate clearly that a correct and unambiguous determination of this distribution for the quiet sun by the eclipse method on meter wave lengths could only be attained at the expense of a considerable increase (10 times) of the accuracy of relative flux measurements (now 1 % for this eclipse).

Mapping of the background radiation (galactic isophotes) on 169 Mc has been completed by A. Koeckelenbergh (1956) for all right ascensions and declinations between -30^{o} and $+90^{o}$. The antenna temperature was 270^{o} K (8.10^{-22}W.m^{-2}.c/s^{-1}) at the galactic center, 15^{o} K at the coldest regions, 75^{o} K at the north equatorial pole and 15 to 30^{o} K in the vicinity of the north galactic pole. The radiosources Cyg. A. and Cyg. X are separated and give rise, as well as Cas. A, to an antenna temperature (beam average) of 130^{o} K. The north polar spur is clearly visible and its main features are similar to those observed on 900 Mc by Denisse, Leroux and Steinberg (CR, Paris, 240.278-280, 1955). The lobe corrections will be brought on the definitive map.

Radioastronomical observation of the Comet 1956 *h* were made in April 1957 by A. Koeckelenbergh on 600 Mc, at the vicinity of perihelion. On April 9th, a flux density amounting to 55.10^{-24} W.m^{-2}.(c/s)$^{-1}$ has been observed. Scanning the sky in the comet region, a maximum flux density has been obtained from April 9 to April 26 in the vicinity of the comet position as calculated from Hasegawa's ephemeris. A tentative interpretation of this observed flux has been made by J. Hunaerts and R. Coutrez.

C) *Publications* :

Mimeographied reports on solar radio observations (monthly, see par. 1). Four months reports on Solar activity (see par. 1).

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II. — Belgian Congo

A radioastronomical observatory is in operation since 1954 at the central Station of IRSAC (Institute for Scientifical Research in Central Africa) at Lwiro (observer : L. van Hemelryck). This station is equipped with a paraboloid of 6 m aperture, equatorially mounted, with automatic tracking of the Sun, and a receiver on 169 Mc (Dicke type switching device until April 1957, single superheterodyne from this date). Mimeographied circulars and publication of solar radio data are now undertaken for routine observations.

This observatory took part, in 1952 and 1954, to a common program of Solar eclipse observations on 169 Mc/s in cooperation with « Ecole Normale Supérieure de Paris » and the Royal Observatory of Belgium.

Canada

Nº 187. — Report of the National Commission V

Since the previous report was presented two years ago, there has been a welcomed broadening of activity in the field of radio astronomy in Canada. This extension of active interest involves the recording and studying of the scintillations of the bright radio star, Cassiopeia, at several stations in Canada, and the proposed program of the University of Toronto to monitor the total solar flux at a frequency of 300 Mc/s throughout the day. Later, accurate measures of the fluxes from the brighter radio stars, as well as the sun, will be obtained at the University.

Solar Noise Observations, 3000 Mc/s

Regular observations of the solar radio flux on a wavelength of 10.7 cm have continued in Ottawa at the National Research

Council, and now extend into the tenth year. During the summer of 1954, the daily values of flux reached a minimum, and have subsequently shown a rapid rise during 1955 and 1956 with the appearance of the present growing phase of solar activity. During the period of minimum solar activity, a partial eclipse of the sun was observed in Ottawa, on June 30, 1954. The eclipse commenced after sunrise and a measure of the decrease in solar radiation from a 2° region containing both sun and moon was obtained with a paraboloidal reflector ten feet in diameter. After the eclipse, when the unobscured sun drifted through the receiving pattern of the 150-foot array, near local noon, the solar emission was recorded in North-South strips approximately 1/8 wide. These two observations were interpreted simultaneously by means of a least-square solution, to show that the radio disc is 1.14 times that of the photosphere, with the equatorial regions on the limb brighter than the polar regions. The equivalent temperature at the center of the radio disc is about 33 000° K.

Observations with the 150-foot array also showed that there were many unresolved features on the solar disc, and that much detail could be obtained with scans made with a sharper antenna pattern. An increase in resolution was attempted by using the existing long array as one element of a new type of interferometer capable of producing a single lobe receiving pattern. The second element was constructed as a double-element interferometer with separation equal to that of the long array, and placed to the west of the long array on the common East-West axis. The two elements thus form an asymmetrical interferometer with an aperture of 300 feet. A rotary phase-shifter, after Ryle, is used in one of the connecting arms, and at the receiver output a synchronous detector is used. The resultant pattern is a single lobe, and consists of the product of three terms : (1) the single-lobe pattern of the long array ; (2) the interference pattern of the simple interferometer, and (3) the interference pattern between the simple interferometer and the array. The overall length of 300 feet (about 900 wavelengths) produces a fan-shaped beam 2° E-W by 2 minutes of arc N-S, and was used to obtain solar drift-curves during the first part of 1956.

The rarely observed absorptive feature after a burst was again observed on March 1, 1956, and the associated flare observed at the

McMath-Hulbert Observatory showed dark absorption matter similarly situated, as in the previously reported flare of May, 19 1951.

Scintillations

Continuous recording of the scintillations of the intense radio star of Cassiopeia have been made in Ottawa by the Defence Research Board, on a frequency of 50 Mc/s, since September, 1953. The records are obtained with an interferometer consisting of two horizontal dipoles separated by ten wavelengths and so oriented that this circumpolar radio star may be observed for 24 hours. During this time the source moves between zenith angles of 13 and 76 degrees. A phase-reversing switch in the cable to one antenna, together with a phase-selective detector, permit the cancellation of the general background. The records were analysed for each hour of the day using only the fluctuation indices of 0 and 1, which indicate respectively « no scintillation » and « scintillation ». The plot of percentage occurrence of scintillations for each hour of the day, against sidereal time, showed the expected dependence upon elevation related to the thickness of ionosphere traversed ; while plotted against local time, the graph showed high daytime values with still higher values occurring during the night — one peak before midnight, and a second peak after midnight. On a yearly basis, the F_2 critical frequency and the spread-F, as well as the K indices, showed a positive correlation with this scintillation curve.

A later and separate analysis of the scintillation data obtained at Ottawa removed the scintillation due to the altitude of the star, and revealed a residual annual effect comprised of five features. The changes in this residual pattern suggest that the sun is not primarily responsible for the variations observed, but rather (after the manner of Ryle and Hewish) that there is a mechanism external to the solar system. An explanation is suggested in terms of the accretion of hydrogen atoms by the sun to form a dense accumulation of particles behind the sun. From this collision region, particles fall towards the sun, and upon striking the earth's atmosphere contribute to the ionization responsible for the scintillations. On this model, analysis shows that the collision region is located 200 million miles from the sun,

and the radiant appears to lie within the limits 16h40m to 16h in right ascension, and within -20^{o} to -40^{o} in declination. The particle velocity with respect to the galactic plane can be estimated to be tangentially 28×10^{4} meters/second, and radially outward 2×10^{4} meters/second.

Measurements of the fluctuations in the intensity of Cassiopeia at 50 Mc/s will be made over a wide geographical region during the I.G.Y., with equipment based upon the Ottawa design : at Churchill, Manitoba, by the Defence Research Board ; at Saskatoon, by the University of Saskatchewan ; at London, Ontario, by the University of Western Ontario, and at Kingston, Ontario, by Queen's University. At times of intense solar activity this equipment may register intense bursts of solar noise. An example from the Ottawa station was reported for January 15, 1955.

Auroral Noise

During a thunderstorm on June 26, 1954, noise signals were observed on a series of frequencies : 492, 173, 91 and 49 Mc/s at R. P. L., D. R. B., Ottawa. Other excess noise has been observed on several channels during March, 1956, and can most readily be explained as originating either in the aurora or in the disturbed ionosphere during a period of enhanced solar activity.

Radio Observations of Meteors and Aurora

Studies of both meteors and the aurora have been made by the Upper Atmosphere Research Section in the National Research Council at Ottawa.

Radar recording of meteor echoes during the active periods of the major annual showers has been continued on a frequency of 32 Mc/s. This work has been carried out in cooperation with visual and photographic recording and has been part of a combined Dominion Observatory-National Research Council study of meteors. Special meteor radar equipment in the same frequency range, designed to give a constant level of performance, is being prepared for continuous operation during the I.G.Y.

Auroral radar echoes have been recorded on 50 Mc/s on a continuous basis at Ottawa since April, 1955. Four identical transmitting-receiving units have been constructed and will be operated throughout the I.G.Y. at Resolute Bay, Baker Lake, Saskatoon and Ottawa.

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Czechoslovakia

N° 173. — Report of the National Committee to Commission V

(*Translation*)

This report gives a survey of the radioastronomical developments from 1950 to the end of 1956. Researches are made at the Astronomical Institute of the Academy of Sciences in Prague and at its observatory at Ondrejov (14°47′ E, 49°55′ N) near Prague.

EXPERIMENTAL RESEARCHES

These experimental researches are concentrated on the Sun and on the localization of Meteors. In 1953, J. Budejicky began with the construction of a radiotelescope for solar observations on 56 cm. The antenna consists in a paraboloïd of 7.5 m aperture, giving a half power beamwidth of 72° in the vertical plane and 55° in the horizontal. This radiotelescope was first used for the observations of the solar eclipse of June 30, 1954 (1). Since

January 1956, after a period of trial and absolute calibrations, the instrument has been used for continuous observations. The results in the form of a circular are now regularly sent to the members of Sub-Commission V*a*.

A radiotelescope of 7.5 m aperture on 1.3 m wave length is now under development. This instrument will be put into use in 1957. On the other hand, a special radiotelescope for the localization of the solar radio sources is planned as an application of the antenna beam deviation method (2).

Concerning the researches on the meteors, construction began in 1956 (Budějicky, Plavkova, Simek) of a special radar working on 8 m wave length, the antenna of which consists in 6 half-wave dipoles placed above a reflector, thus giving a beamwidth of $36^{o} \times 50^{o}$. This antenna will rotate continously in azimut. The instrument is intended for determinations of hourly rates, linear electronic densities, trajectories and geocentric velocities of meteors. Completion is expected for 1957.

Theoretical researches

Eclipses of radiosources by the solar corona were studied theoretically by Link (3) on the base of a regular refraction in the coronal ionized medium. These results were used by Hewish in a comparison with the eclipse observations of the source 05.01 Tau, for eliminating this mechanism at distances greater than 10 solar radii at the profit of diffraction by coronal irregularities.

Ionospheric effects on the propagation of radioastronomical waves were discussed by E. Chvojkova and F. Link (4) in an analysis of lunar echoes obtained by Kerr and Shain in Australia on 20 Mc. It was shown that a simple theory of the refraction gives a better agreement with observational results that the Bremmer's theory modified by Kerr and Shain.

Attention has been brought by F. Link and L. Neuzil (5) on a series of lunar occultations of radiosources in 1955-1957; the authors calculated the Bessel elements for 20 occultations of the source 05.01 Tau and for 17 occultations of the source 06.01 Gem. After this suggestion, the Nautical Almanac began a regular computation of the ephemeris which are now distributed to interested observatories. After the theory of Link (6, 7), these occultations offer a very sensitive criterion for traces of a lunar

atmosphere. Using these results, B. Elsmore and G. R. Whitfield were able to reduce the upper limit of the lunar atmospheric density to 10^{-12} of the terrestrial atmosphere, the previous optical limit being 1000 times higher.

On the basis of the Freiburg data, L. Neuzil studied the critical frequencies of the sporadic E layer in connection with solar and meteoric activity. It was shown (8) that E*s* acts in diurnal conditions like a Chapman region with n equals approximately 1/4. Evidence of meteoric shower influence appears for the Perseids, the Orionids and for the day-time showers Perseids and Arietids (9, 10, 11).

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France

N° 237. — Report of the National Committee to Commission V

(*Translation*)

Radioastronomical studies in France are made by two working groups. The most important one is installed at the Meudon Observatory ; its radioastronomical station is located at Nançay (Cher), 200 km south of Paris. A second group works at the « Institut d'Astrophysique » and since 1954, is establishing an observing station at the Observatory of St-Michel, Haute Provence.

A. — Radioastronomical Department, Observatory of Meudon

I. — *Solar Observation*

(*a*) *Total radiation of the Sun, routine measurements* :

1. Routine measurements of the Sun on 169 Mc/s, interrupted previously, were resumed and are now made regularly during the whole day from March 1957. Similar measurements will be made in Tahiti during the IGY.

2. Measurements on the same frequency of 169 Mc/s, made simultaneously in Paris and Goteborg during the eclipse of June 30, 1957, confirmed the elliptical shape of the quiet sun's corona.

3. Absolute measurements of the quiet sun's flux density at sunspot minimum, made on 33 cm wave length, led to apparent temperatures of 400 000° K for a solar diameter of 31′ (1).

4. Interferometric measurements on 3 cm wave length with variable spacing confirmed the existence of a limb brightening (5).

(*b*) *Radiation of the active Sun* :

1. A systematic survey of the Sun's activity is made each day during 2 hours with the large interferometer of Nançay on 169 Mc/s (2), at the vicinity of meridian transit.

2. A fourth type of solar burst was identified (3). This type associated with very intense flares is observed a few tens of minutes after the outburst, and has a duration of the order of one hour ; the diameter of the emission area is of the order of 10′. This radiation does not include any type-I burst.

3. An extensive study was made of the emission centers responsible of noise storms (enhanced radiation). The altitude of these centers is of the order of 200 000 to 400 000 km ; the apparent diameter, in any case inferior to 6′, may be less than 1′. The mean duration of an isolated center is less than 6 days. Evidence was found of a trend for several activity centers to operate simultaneously at different heliographic longitudes (4).

Charts showing day to day variation of these activity centers are now in course of publication in the *Quarterly Bulletin of Solar activity.*

2. A special interferometric device (see par. VII) has been used for studying the apparent diameter of the active solar sources on 3 cm wavelength. An average diameter of 5′ was measured for the « quiet » spots responsible of the slowly varying component. Sources of bursts have a diameter of several minutes of arc ; exceptionnally, a few sources of less than 1′ diameter were observed (6).

II. — *Galactic observations*

(*a*) *Background radiation and radiosources on* 33 *cm wavelength.* — A complete map of the sky was established on 33 cm wavelength, showing at least 20 isolated sources in the vicinity of the galactic plane ; some of these sources are new. A diffuse background limited to some 20° north and south of the galactic plane was also observed as well as a few extented sources, one in Herculis, another one between Cassiopeia and the North pole (8, 1, 9, 21).

— Absolute measurements were made of the most intense radiosources on the galactic crest (1, 10) and of the background, the temperature of which is found to be less than 3° K.

— An analysis of these results led, in particular, to an evaluation of the average electronic density in the nearest galactic spiral arms (ca. I électron.cm^{-3}), and to a more precise determination of the radiosources and of the background radiation spectra (4).

(*b*) *Eclipse of the Crab Nebula by the Moon.* — This eclipse was observed on Jan. 24, 1956 on 177 cm and 33 cm wavelengths. The eclipse curve on 177 cm showed that the emissive region is concentrated in the inner part of the nebula (amorphous mass) ; it seemed that, on 33 cm, the radiation of the external filaments

is relatively more pronounced. The optical and radioelectrical centers of the nebula are coincident up to 5″ (11).

c) *General study of radiosources on* 169 *Mc/s.* — A systematic study of the radiosources observable from Nançay with the large interferometer has been undertaken. The first measurements show that results could be expected (right ascension up to 15″ accuracy, apparent diameter or structure) for at least 100 radiosources.

III. — *Lunar observations*

1. Measurements of the thermal radiation of the Moon were made during several lunations on 33 cm and 3 cm wave lenggths. On 3 cm the variation during a cycle attains 40 % with a phase difference of 7 days with respect to the visible light. On 33 cm, however, no variation greater than 5 % (sensitivity limit of the observations) has been detected (1).

2. The analysis of the eclipse curves of the Crab Nebula by the Moon has shown that the electronic density of the lunar atmosphere is less than 10^4 electrons.cm^{-3} (11).

IV. — *Solar and terrestrial relationships*

1. A study was continued of the relations between the optical, radioelectrical and geomagnetic properties of sunspots. In particular, in separating the sunspots with strong flare activity and weak radio activity, and conversely, it was shown that geomagnetic activity which follows the transit of certain spots at the central meridian is more closely related to their radioelectric activity than to their flare activity (12, 13).

2. It was shown that the occurrence of a large flare on a radioelectric spot is followed on the same day by an increase of the geomagnetic activity, independently of the apparent position of the flare on the solar disk. This magnetic activity has a different character from that associated with the transit of R-spots at the central meridian (14, 15).

3. Evidence was shown of a proportionnality, which persists on the whole cycle of solar activity, between the global radiation of the Sun on 10 cm wave length and the ionizing flux $((f_0 E)^4 . (\cos Z)^{-1})$ on the E layer (7).

4. It was shown that the meridian transit of the R-spots is on the average in connection with a decrease of foF_2 during the night. No significiant variation of foF_2 occurs after the transit of Q-spots, or after the transit of R-spots in daytime conditions (16).

5. In view of the determination of a radioelectric solar index (recommendation of the Sub-Commission Vc, U.R.S.I.) a study was made of the noise storm spectra at various intensities (17).

V. — *Observations related with properties of the terrestrial atmosphere*

(*a*) *Solar radiation on* 3 *cm-wave length.* — Observations of this solar radioflux have given the following results :

— estimation of the atmospheric refraction on this wave length (values found comparable to those of optical refraction) ;

— estimation of atmospheric absorption (neatly more pronounced than atmospheric attenuation computed on the basis of an homogeneous atmosphere of oxygene and water vapour)(19) ;

— evidence of scintillation phenomena and study of this scintillation ; the r. m. s. amplitude of the scintillations is proportional to sec z ; the pseudo period is proportional to $(\sec z)^{1/2}$. The amplitude of scintillation depends on the presence of localized radiosources on the Sun. Similar measurements made on 33 cm wave length have shown that this type of scintillation does not increase in amplitude with increasing wave length. Observations made simultaneously by means of 2 or 3 antennas at variable spacings led to estimation of the dimensions of the «shadows» on the ground (order of 100 m) and of the « wind » velocities in the scattering region (order of some 10 m/sec) (20).

(*b*) *Galactic radiation on* 10 *m-wave length.* — Observations of this radiation were used in 1956 for ionospheric absorption measurements ; analysing the possibilities of this method for regular determinations, it was found that some difficulties occur in the interpretation of the observed results, because of the impossibility of separating in every case the D and F_2-layer effects.

VI. — *Theoretical interpretations*

(*a*) *Turbulence in the corona.* — The directivity of radioemission from sunspots was used for calculating the effective altitude of this emission. The data were analysed on the basis of radio-

propagation in turbulent atmospheres, and led to an estimation of a turbulence pattern in the lower corona ; these results were also compared with the data obtained from coronal occultations of the Crab Nebula (23).

(*b*) *Plasmas.* — Studies on the plasma properties were continued, with principal attention on time variation of the isotropic part of the electronic distribution function (24, 25, 27, 26) and on the influence of collisions on this time variation. This theory was applied to interaction phenomena in the ionosphere (Luxemburg effect) (28).

(*c*) *Antenna theory in radio astronomy.* — Radiotelescopes are considered as space-frequency filters with low frequency bandpass. Possibilities for obtaining a flat response were investigated. The array 0, 1, 4, 6 has this property. Investigation was made on the aerial distribution giving optimum information (29). The physical interpretation of mathematical theories on the approximation of functions by means of trigonometric polynomials gives a good explanation of the image defects, as well as the most suitable shape of the space-bandpass of the antenna. Numerical methods were developed in view of image transformations, using the obtained data with the greatest efficiency. A superior limit of the apparent diameter of the radiosources was sought for the case of unsufficient resolving power, without assumption concerning the shape of the radiosources under investigation (30, 31).

VII. — *Technical developments*

a) Interferometer with 4 antennas on 3 cm-wave length : as an application of the general antenna theory, a 4-antenna array $(0, a, 4a, 6a)$ with $a = 60$ wavelengths was established and used for solar studies at sunspot minimum (29).

(*b*) An interferometer with 2 equatorially mounted antennas, with a spacing of 60 m (on 3 cm-wave length), and following the sun during the whole day : as the apparent distance of the antennas is variable, the structure of the stable solar phenomena can be determined (6).

(*c*) Theoretical study of the mixers, in view of determinating the characteristics of the equivalent quadripole : from this study,

optimum performance can be obtained for such mixers ; a receiver on 900 Mc was developed on its basis.

(*d*) Large interferometer on 169 Mc/s : 8 antennas in May 1956, 16 in November 1956, 32 in April 1957. Resolving power ca 3′ (base length 1550 m), interlobe 2°, sensitivity limit 10^{-25} W.m^{-2}. (c/s)$^{-1}$. For sensitivity requirements, this instrument makes use of 16 preamplifiers placed between groups of 2 antennas. Each antenna is formed by a parabolic mirror of 5 m aperture with meridian mounting (total receiving surface 640 m^2) (2).

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B. — Group of the « Institut d'Astrophysique » and the « Observatoire de Haute Provence »

1. — *Observations of radiosources*

This small group which has been at the origin of radiosolar observations at the observatory of Meudon, concentrates its present activity upon the establishment of instruments for radiosource observations.

Two of the parabolic cylindre aerials, described in Sydney in 1952 by M. Laffineur, have been completed at the Observatory of Haute Provence. They gave good results with respect to power gain (absorption cross section) and directivity. The beam orientation device of this antenna was investigated experimentally and found satisfactory. This device will be described in detail in the course of the General Assembly. During the present year, M. Laffineur and P. Coupiac experimented an interferometric device without transmission lines, using only directed beams. This installation begins to work; some of the delicate problems involved have recently received a solution.

The aim of the installation is twofold :

— Observations of radiosources on 300 Mc/s with a antenna spacing of 1000 wavelengths.

— Realization of a large interferometer using high frequency directed beams for long distance interferometry in the site of the Observatory, where the optical horizon lies in some direction at a distance of 100 km.

(See bibliography for recent publications).

II. — *Solar observations*

— Observations of the solar eclipse on June 30, 1954 in Hagaby (Sweden) and in Meudon on 255 and 555 Mc/s (1).

Reduction of data has shown that the residual flux was less important than at the Karthoum eclipse (11 % in 1954 against 19,5 % in 1952) (2, 3, 4). This fact could be related with the coronal variation during the solar cycle (5).

III. — *Galactic radiation and ionosphere*

Observations of the galactic radiation at 18 Mc during more than one year with a receiver giving the minimum level of the galactic noise in spite of interference of atmospherics and very powerful transmitters. This device supplements the classical ones for ionospheric studies (6).

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C. — Miscellaneous items

In addition, correlations between various aspects of solar activity were investigated by B. Vauquois.

Evidence was found of the influence of position and age of sunspots on the 2800 Mc/s emission of solar activity centers (1). A systematic study was untertaken on the correlation between activity centers on centimetre and decimetre waves, sunspots (area, position, age), faculae (area, position, age, intensity). Darkening and aging curves of radioelectric area with respect

to spots and faculae were established. Selection of a great number of samples for different periods during the solar cycle on 8 wavelengths might lead to a determination of the goniometry and evolution of the solar radioelectrical activity centers.

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Germany

Nº 194. — Report on German Work in Radio Astronomy 1954-1956

This report summarises the work on Radio Astronomy which has been carried out in both parts of Germany since the report to the XIth General Assembly in 1954.

At *Berlin-Aldershof* (Heinrich Hertz-Institut für Schwingungsforschung der Deutschen Akademie der Wissenschaften, Director : Prof. Hachenberg) regular observations of the intensity of the solar radio emission have been made at wavelengths of 20 cm and 3.2 cm since Sept. 1954. Recently observations were started at a wavelength of 10,2 cm. The results have been communicated to the *Quarterly Bulletin of Solar Activity*. A 1.2 cm and a 15 cm solar-noise receiver have been completed, they will be in action during the International Geophysical Year.

The distribution of radio intensity across the solar disk at 20 cm wavelength has been deduced from observations of the sun during the eclipse 1954 June 30th. The results are in fairly good agreement with the interferometer measurements. G. Wallis calculated the distribution of the thermal emission across the solar disk for special coronal models and compared his results with the observations.

In order to get an accurate knowledge of the intensity distribution in the spectra of extra-terrestrial radio sources, precise absolute flux measurements in the decimetre-wavelength range have been prepared. Much effort has been spent in the construction of

different accurate noise power standards and in improving the techniques of observation. Several special antennas with definite gain are under construction.

The construction of a radio telescope of 36 m at Berlin-Aldershof started in september 1955. The telescope is movable only in the meridian. But the dipole feed is steerable in the focal plane, so it can follow the daily motion of the objects for about an hour. It is hoped that preliminary tests will be possible during June 1957. The 25 m-radiotelescope of the *Bonn Observatory* (Director Prof. Fr. Becker) on the Stockert Hill was officially dedicated on Sept. 17th, 1956. Details on the construction of the telescope and the 21 cm-receiver are given in Telefunken Zeitung vol. 29, No. 113. The mounting of the antenna is of azimuthal design, for the conversion of the coordinates an analog computer will be used. As the tests indicate, the surface of the disk is a true paraboloid within ± 4 mm.

During the winter 1956-57 the technical equipment of the telescope has been completed but the driving system will not be ready before May 1957. The adjustment by the usual astronomical methods was made by means of an optical telescope of 10 cm aperture, whose axis is parallel to the geometrical axis of the paraboloid. The setting of the antenna is of the order of one minute of arc after certain systematic corrections depending on azimuth and elevation.

A first provisional observing programme may be started in April 1957.

At the *Fraunhofer-Institut Freiburg i. Br.* (Director : Prof. Kiepenheuer) solar noise observations have been made at 2600 Mc/s with a paraboloid of 3 m diameter. A solar spectrograph for the frequency range 48-165 Mc/s is under construction and will probably be ready for the IGY. The effective area of the antennas is 10 m^2, the range is covered by a system of 6 receivers twice a second.

At the *Kiel Radio Observatory* (Director : Prof. Unsöld) the preliminary radio telescope (dipole array 5×5 m — 7×3 dipoles, altazimuth mounting) has been used on a frequency of 198 Mc/sec for the following programs :

1) Observation of the partial solar eclipse on June 30, 1954.
2) Radio survey of the sky north of $\delta = -20^{o}$.

At the beginning of October 1956 the old antenna has been taken down. Test observations of solar activity on 198 Mc/sec have been carried out with a simple corner reflector during October and November 1956. A 7.5 m paraboloid is now under construction about 30 m south of the position of the old radio telescope. It will be used for observations of solar bursts, simultaneously at two frequencies about 10 Mc/sec apart centered at about 130 Mc/sec.

The radioastronomical section of the *Astrophysical Observatory Potsdam* (Dr. Daene) has continued the development of instrumental equipment. Various receivers from 50 cm to 3 m wavelength are now available, simple as well as switched. Another receiver ranging from 12 to 17 m wavelength will be used for solar work in the IGY. The station, fifteen miles south of Potsdam has two parallactic mounted aerials of 10,5 m and 3,5 m diameter. Two other parallactic mounted aerials of 10,5 m and 7,5 m diameter are nearly completed. Two fixed aerials, 12 m diameter, distance about 300 m, have been used for frequency switching interferometer experiments. Since Sept. 1956 routine observations of solar flux have been made at 1,7 m wavelength. Solar observations are intended at various frequencies in the IGY.

Theoretical work has been devoted to the influence of diffraction in measurements of the position and the diameter of radio-sources by occultations by the moon (M. Schubert). Another theoretical study has been made on astronomical scintillation including the scintillation of discrete radio-sources (H. Scheffler).

At the *Astronomical Institute of the University, Tübingen* (Director : Prof. Siedentopf) different experimental work is in preparation. Solar noise observations are intended at 4000 Mc/s with a paraboloid of 3 m diameter, and the scintillations of radio sources shall be observed at 47 Mc/s. G. Elwert and H. Siedentopf calculated the resolution of circular radio sources by Michelson interferometers in connection with the resolution of details on the solar surface.

At the *Max Planck Institut für Physik, Göttingen* (Director : Prof. Biermann) the theoretical work on Radio-Astronomy and Plasma-Physics was continued.

In connection with the contribution of R. Lüst about « Shock-waves and plasma oscillations in a magnetic field » at the U.R.S.I.

General Assembly in the Hague, two papers were published by Lüst, in which these questions were discussed in more detail. It is shown that for plasma oscillations in a magnetic field, the Poynting vector does not vanish and radiation can be emitted. The problem of the energy of the solar non-thermal radio frequency emission was discussed by L. Biermann and R. Lüst in connection with the heating of the solar chromosphere and corona. It was proposed that the whole non-thermal emissions of the Sun are maintained by acoustic waves originating in the hydrogen convection zone according to the ideas of Biermann and Schwarzschild. A. Schlüter discussed the question of solar radio emission and the acceleration of magnetic-storm particles. He proposed a mechanism, that not magnetized material is ejected and moves between the magnetic lines of force of the general magnetic field of the sun. The material then behaves as if it were a diamagnetic body, and the Maxwell tensions of the magnetic field produce an accelerating force (« melon seed mechanism »). The work on the theory of a plasma was continued by A. Schlüter and reported at the Symposium on Electromagnetic Phenomena in Cosmical Physics, Stockholm 1956.

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Italy

N° 162. — Report of Commission V of the National Committee

Radio Solar Work at Arcetri, Florence

A total power radiometer working on a frequency of 221 Mc/s has been installed at the Arcetri Observatory near Florence for solar work.

The antenna, equatorially mounted, and driven by an electric motor, is composed of four helices mounted on a back reflector of about 25 square meters of surface.

The receiver which is a conventional superheterodyne is switched off every hour to a noise diode giving a reference signal. Twice a day a temperature calibration is performed by means of the same diode.

The receiver has a band of 2 Mc/s and a time constant of 2 seconds. The output is recorded with an Evershed and Vignoles milliammeter of 1 mA full scale deflection.

The noise figure of the instruments has turned out to be about 7 *db* ; the maximum sensitivity of the recorder is 10 °K per 0.01 of the full scale deflection. The fluctuations of the receiver noise are well below this limit thanks the accurate regulation of the power supply.

The radiometer is in operation since the beginning of 1957.

Japan

N° 201. — Report of Commission V of the National Committee

Y. HAGIHARA

1. — RECEIVING TECHNIQUE

(*a*) *Polarization.* — At the Research Institute of Atmospherics at Toyokawa, radiometers for use at 9400, 2000 and 1000 Mc/s have been added to a 3750 Mc/s radiometer. To facilitate inter-

comparison, all the paraboloids are made in similar figures. Each has a similar feed-antenna of a circular waveguide connected to a turnstile circuit for separating two circular polarizations. Equipment for use at 1000 and 2000 Mc/s have mechanical switches and electronic dividers to indicate directly the percentage polarization of outstanding occurrences. Equipment for other frequencies have static switches using ferrite and the sum and difference of two polarizations are recorded continuously (1).

At the Tokyo Astronomical Observatory, a radiometer for use at 9000 Mc/s has been completed. At the focus of a 1.1 metre dish, a circular horn is attached to the quarter-wave-plate which rotates at a velocity of 1500 rpm. Three reference signals are mixed with the output of a radiometer and each detects the four Stokes' parameters separately. A static modulator is also used here (2).

Also at the Tokyo Astronomical Observatory a time-sharing radio polarimeter has been constructed for determining the polarization of the solar radio burst at 200 Mc/s. A pair of crossed dipoles are attached to the 10 meter paraboloid and their outputs are combined with suitable phase delays. By the use of time-sharing scheme and electronic switch, six components of polarization, i. e. four linear and two circular components, can be obtained simultaneously (3, 4). In connection with this equipment a new type of square-law detector has been developed (5).

(*b*) *Interferometer.* — A new type of radio interferometer called as the « phase-switching multiphase interferometer » for locating the sources of solar radio bursts has been developed. Four interference patterns are obtained by inserting phase shifts of $-\pi/4$, 0, $\pi/4$ and $\pi/_2$ in the phase-switching interferometer. The position of the source can be determined without the help of a radiometer. Moreover the position can be determined by a simple eye-inspection of the signs of the deflections on the four traces. The accuracy of this eye-inspection is ± 0.6 minutes of arc in the present equipment which has the baseline of 340 wavelengths at 200 Mc/s (6).

2. — The Sun

(*a*) *Quiet sun.* — H. Tanaka compared the monthly mean values of the flux measured both at Ottawa (2800 Mc/s) and at Toyokawa

(3750 Mc/s) and found that two series of observations agree more precisely if the background radiation, which varies according to the Sun's declination, is substracted from the values obtained at Ottawa (7).

(*b*) *Enhanced radiation.* — A model for the solar enhanced region at centimeter range has been derived from the observation of the partial solar eclipse on June 20, 1955. The observation was made at three stations with three radiometers (two at 3000 Mc/s and one at 3750 Mc/s) and an eight-element interferometer (4000 Mc/s). On the day of the eclipse a group of sunspots was seen on the -S-W part of the solar disk and the radio observation has enabled to deduce the radio isophotes of the enhanced region around the spot. The location and size of the radio spot is found to be very similar to those of the calcium plage around the spot. The brightness temperature is found to be around 10^6 °K. The detailed analysis showed the existence of the limb brightening at the equatorial region. The work are conducted jointly by the Tokyo Astronomical Observatory and the Research Institute of Atmospherics (8, 9).

T. Kakinuma measured the polarization of the radiation from individual radio spot by an eight-element interferometer at 4000 Mc/s. It is confirmed by the directed measurement that the sense of polarization varies gradually according to rule found by Piddington and Minnett, though the sense at each quadrant on the solar disk has been reversed in the present solar cycle (10).

(*c*) *Bursts and outbursts.* — The nature of solar radio bursts at frequencies around 3000 Mc/s is studied statistically by K. Akabane. It is found that the number of bursts does not increase monotonously with decreasing intensity but shows a maximum for bursts with the intensity of 5 to 10 units. (1 unit is 10^{-22}w.m^{-2}(c/s)$^{-1}$). The number of bursts decreases as $I^{-1.8}$ for bursts with intensity greater than 5 units, where I is the intensity of a burst. The frequency distribution of the number of bursts over the solar disk is derived. If this frequency distribution is interpreted by assuming a absorbing layer above the source of a burst, the optical thickness of the layer is about 0.3 or 0.4 (11).

H. Tanaka and T. Kakinuma estimated the position and size of the source of the most intense solar radio outburst on

February 23, 1956 by the multiple element interferometer. The position of the radio source at 4000 Mc/s was in good agreement with the center of the flare. The most probable E-W width of the radio source during the outburst is 3 minutes of arc, which corresponds to the maximum effective temperature of about 5×10^8 °K (12).

By analysing the interferometer records at 200 Mc/s S. Suzuki and M. Morimoto have found that the positions of burst sources have a scatter of several minutes of arc which is comparable to the extension of the calcium plage.

The polarization observation of bursts at 200 Mc/s has been started since December, 1954, by a time-sharing polarimeter at the Tokyo Astronomical Observatory. The observation has been continued until October, 1955 (3, 4). By these observation it was found that the accuracy of the equipment was not sufficient enough to discuss the details of the polarization. Then the equipment was reexamined to improve the accuracy. The observation has been started again in April, 1957, with a revised system. Recent observation shows that most bursts are purely circularly or randomly polarized and a few bursts are mixture of circularly polarized component and randomly polarized component.

T. Hatanaka showed that the axis of a polarization ellipse rotates by the Faraday effect in the solar atmosphere and the earth's ionosphere and also pointed out that the linearly polarized component is made random because of the finite bandwidth of the receiver (13).

(*d*) *Emission mechanisms.* — T. Takakura proposed a theory for the emission mechanism of polarised bursts and noise storms. He assumes an ordered gyration of electrons in the magnetic field of a sunspot. The radiation thus emitted is extraordinary ray and is to be absorbed in the upper layer where the refractive index for the wave approaches to infinity. If, however, there is a layer where the magnetic field and or the electron density changes steeply along the path of the wave, a part of the wave can be transformed into an ordinary wave. The ordinary wave thus created can propagate through the solar atmosphere and will be observed as a radio burst (14).

He also proposes to explain the so called background continuum of noise storms by the superposition of many spikes which occur

at random and whose amplitude are distributed with a probability density law. At least 80 % of the enhanced level at a noise storm can be explained by using the present hypothesis. So called storm bursts seem to be the fluctuations around the mean level and are the superposition of at least a few spikes (15). This hypothesis is also checked by him by measuring the low frequency spectrum of the waveform of noise storms. The spectrum gives good agreement with the present hypothesis, if each spike has the shape which rises linearly with time to its maximum intensity and declines exponentially with the time constant of the order of a few seconds (16).

3. — The Moon

The lunar radiation was observed by K. Akabane at 3000 Mc/s with the 10-metre paraboloid. The maximum and minimum temperatures at the center of the moon's disk are found to be 390° (±50°)K and 240°(±50°)K, respectively, if an ordinary temperature distribution on the lunar surface is assumed. The maximum temperature is observed a few days after the full moon (17).

4. — Observing Problems

The solar radio observations especially at meterwave region are frequently disturbed by man-made interferences and atmospherics. A method to discriminate these disturbance is developed by K. Kawakami and others. The method consists to record the ratio of the *dc* outputs from two different types of the second detector. The one detector has a time constant of 1 microsecond while the other thas a time constant of 1 millisecond. The ratio of these outputs depends critically on the wave form but not on the amplitude of the IF signals. If the ratio for the solar radiation is set to a fixed value then *cw* signals and pulsive noises are easily detected by this method (18).

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Netherlands

I. — Netherlands' foundation for radio astronomy

Observations until July, 1955 have been made at Kootwijk with a 7.5 meter paraboloid. The present radio observatory is located at Dwingeloo and has a 25 meter paraboloid telescope, completed April 1956, two 7.5 meter telescopes and a 3.03 × 3.76 meter pyramidal horn. The beamwidth of the large telescope is 0°57 at 1420 Mc/s and 2°0 at 400 Mc/s. The main research programs carried out in close cooperation with the observatories at Leiden and Utrecht are listed below.

Subject	Main results	Status, May 1957
1. Hydrogen distribution in spiral arms of galactic system (21 cm, Kootwijk)	Map of spiral arms in galactic system. Cross-sections through spiral arms perpendicular to galactic plane. Preliminary determination of galactic pole : $l = 322°$, $b = 88°6$.	*B.A.N.* n° 475 with full catalogue of profiles and detailed results appears this month.
2. Hydrogen in stellar associations (21 cm).	Zeta Persei and Lacerta : no excess of hydrogen density (Kootwijk). Orion : interesting details (Dwingeloo).	Kootwijk: *B.A.N.* 475. Dwingeloo : observations in progress.
3. Hydrogen at high latitudes (21 cm).	Low-temperature peaks (2-8° K) with extended wings (several 100 km/sec) found in almost any direction. Kootwijk results are fully confirmed at Dwingeloo.	Preliminary results in Publ. Jodrell Bank Symposium. New data for four standard fields are available.
4. Hydrogen near center of galactic system (21 cm).	Much detail in line wings. One spiral arm is seen in absorption in front of Sgr A source. It moves at 50 km/sec away from center.	Preliminary results published (Comptes Rendus).

Subject	Main results	Status, May 1957
5. Hydrogen in absorption in front of strong sources (21 cm).	In front of Cas A are 3 heavy components and 3 weak ones. Accuracy 1 %. Line width corresponds to gas temperatures of 300 to 800° K. Less complete measurements on Tau A.	First results submitted for publication (*Ap. J.*)
6. Hydrogen emission from Andromeda Nebula (21 cm).	Line profiles measured to 2°5 from center. Accuracy 0°3 K. Rotational velocity and hydrogen density of system. New determination of its total mass.	Completed and submitted for publication (*B.A.N.*).
7. Hydrogen emission from other galaxies and clusters of galaxies (21 cm).	Positive results in tests on M33 and M51. Negative results in tests on M81 en NGC 205.	Preliminary test only. Special wide-band equipment for more complete observations is under construction.
8. Map of Galactic belt (22 cm).	In the region $l = 320°$ — 20°, clear superposition of narrow ridge and numerous discrete sources with diameters up to 1°5. Beyond $l = 60°$ hardly any detectable radiation.	Kootwijk : Center region *B.A.N.* 472. Dwingeloo : Isophote maps completed. Further reduction in progress.
9 Search for point sources (22 cm).	Visible sky fully covered with rapid sweeps. Only 3 sources with $S > 0.5 \times 10^{-24}$ at latitude $b > 5°$. Intensity ratio of strong sources within 1 %.	Reduction completed.
10. Map of entire sky (75 cm).	Sky fully covered with accuracy 1° K. Andromeda nebula and Moon well measurable ; Coma cluster just visible (1/2° K). Relative brightness levels of regions outside galactic belt accurately established. Intensity ratios of strong sources within 1 per cent.	Preliminary observations published : *B.A.N.* 475. Full observations completed. Reduction just started.

Subject	Main results	Status, May 1957
11. Comet observations (75 cm).	Comet invisible down to $S = 2 - 10 \times 10^{-25}$ in 18 days of observation.	Preliminary results I.A.U. Announcement card May 1957.
12. Absolute intensity of strong sources (75 cm).	Method planned for several frequencies involves gain calibration by horn and detector calibration by means of refrigerated load.	First tests made : *B.A.N.* 472.
13. Brightness distribution in Tau A (75 cm).	Two occultations of Tau A by Moon observed in Nov. 1955. Brightness distribution fairly uniform. Size equals that on 20 m Palomar photographs of amorphous light.	Submitted for publication (*B.A.N.*).
14. Solar bursts with high time resolution (75 cm).	Two-open recorder with good response up to 100 c/s registers bursts and flares. Single bursts of 1/4 quiet sun level have average durations of 0.18 sec between halfpower points. Several flares observed.	Observations continue. Only a few samples have been reduced. Plans for simultaneous observation at adjacent frequencies.
15. Extinction, refraction (21 cm, 22 cm, 75 cm).	Byproducts of calibration. procedures in other programs. Present extinction value in zenith : 0.037 db at 21 cm. Present data give combination of refraction and mechanical deformation of the antenna.	Only preliminary data available. Cf. *B.A.N.* 472, 475.
16. Scintillation (22 cm, 75 cm).	Byproducts of other programs. Scintillation of 5 or 10 per cent is normal at low altitudes at 75 cm, but occasionally measurable scintillation occurs in strong sources in any position on the sky.	Some data in *B.A.N.* 472.

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DE INGENIEUR, N° 3, 1957. — This volume contains as set of articles on engineering aspects of the 21-meter telescope at Dwingeloo (In Dutch).

II. — SECTION « IONOSPHERE AND RADIO ASTRONOMY » OF THE POSTAL AND TELECOMMUNICATIONS SERVICES

The section « Ionosphere and Radio Astronomy » continued its daily observations of solar radio noise on 200 and 545 Mc/s. In the course of 1956 observations on the frequency 2980 Mc/s were added to the routine observation program.

Sources of enhanced radiation on the sun were localized with an interferometer (spacing 100 wavelength) operating at the frequency 255 Mc/s. The total flux observations at 200 Mc/s were supplemented by polarization measurements on the same frequency. These measurements were recorded by a high-speed instrument (Brush recorder). In the summer of 1957 new polarization equipment will be put into use, by means of which the complete state of polarization (4 components) will be determined.

The radio observations were supplemented with visual observations. (Sunspot sketches and flare patrol).

The results of the routine observations were published in the « Monthly Bulletin », issued by the Royal Netherlands Meteorological Institute. An analysis of high speed records is described in IRA-Report N° 10, an account of the interferometer position determinations is given in IRA-Report N° 12.

Sweden

N° 217. — Report of the National Committee to Commission V

(Olof E. H. RYDBECK)

The Swedish activity in the field of radio astronomy has been concentrated mainly to the Onsala Radio Wave Propagation

Observatory (57°24′ N; 11°55′ E) of the Research Laboratory of Electronics of the Chalmers University of Technology, Gothenburg, Sweden.

Experimental work

(*a*) *Solar noise.* — Solar noise is recorded automatically on 150 Mc/s with a recording equipment using an equatorially mounted Würzburg 7.5 m paraboloid. The antenna follows the Sun from sunrise to sunset.

(*b*) *Scintillation of radio stars.* — The ionospheric and auroral scintillation of Cygnus and or Cassiopeia is recorded on 33 and 150 Mc/s. Groups of Yagi antennas (on 33 Mc/s) and a matress antenna (100 m^2 absorption cross section) are used for these measurements.

A long base interferometer (base line about 1200 m) is under construction.

(*c*) *Meteor radio echo studies.* — The meteor recording equipment, pulse power output 100 kW, wavelength 9.1 m, is regulary in operation during the main meteor showers.

(*d*) *Recording of galactic hydrogen on 21 cm wave-length.* — The hydrogen line recorder is now in regular operation. A Würzburg equatorially mounted 7.5 m paraboloid is used as antenna for the equipment. A bigger paraboloid of 10 m is under construction. Observational programme organized in co-operation with the Stockholm Observatory, Prof. Bertil Lindblad.

Theoretical Work

Final reductions of June 30, 1954 solar eclipse data (on wavelengths 10.21 and 200 cm) have been completed.

A preliminary survey of the results of the scintillation studies, including a discussion of the auroral rate step effect, has been prepared and is in the process of publication.

A detailed account of the results of the 1953 series of combined visual and radar observations of Perseid meteors has been published. Reports of the 1955 and 1956 recordings are in preparation.

A theoretical examination has been made of the coupling between plasma waves and electromagnetic waves in the solar corona, with possible applications to the problem of the generation of enhanced solar noise and out-bursts.

A final report of the Kiruna auroral echo observations has been prepared. The great majority of the echoes observed are attributed to the aurorae.

The problem of the stability of the proposed extra terrestrial current ring has been discussed and surveyed theoretically by N. Wax (Guggenheim Fellow 1954-1955).

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The following papers have been published, or are in course of publication, in technical or scientific journals :

1. H. Wilhelmsson. — The interaction between an obliquely incident plane electromagnetic wave : Part. I, Reports from the Research Laboratory of Electronics, nº 32. *Trans. Chalmers University of Technology*, **155**, 1954 (Part II : in process of publication).
2. N. Wax. — A note on design considerations for a proposed auroral radar : Reports from the Research Laboratory of Electronics, nº 40. *Trans. Chalmers University of Technology*, **182**, 1957.
3. N. Wax. — On the ring current hypothesis : Reports from the Research Laboratory of Electronics, nº 41. *Trans. Chalmers University of Technology*, **171**, 1956.
4. B.-A. Lindblad. — Combined visual and radar observations of Perseid meteors, I. Observations in 1953 (Dissertation), Reports from the Research Laboratory of Electronics, nº 36, 1956.
5. S. Olving, J. Meos. — On the Origin of Radar Echoes Associated with Auroral Activity (In course of publication).

Summary : An analysis of the auroral echoes at 10 m wavelength, recorded at the Kiruna Radio Wave Propagation Observatory during the first quarter of 1953, indicates that the echoes cannot be disconnected from aurora borealis. It is concluded that the predominant echo mechanism is closely connected to ionized and normally invisible auroral forms. These forms are assumed to be directed along the geomagnetic field lines. It is further very likely that the scattered power received has a strong maximum when the radar wave intersects the ionized auroral geometry perpendicularly, assuming the receiver and transmitter to be situated at the same place. It is not possible to obtain this perpendicularity for a radar at Kiruna except in a very narrow region, if the minimum height, where the scattering takes place, is of the order 90 km. However, the well known sharp maximum of visible auroral activity lies within the E-region, where one normally has a thick auroral ionized layer present (14). Whatever the detailed mechanism of the scattering is, it seems to be important to call attention to the fact that the scattering probably takes place in a medium, i. e. the auroral E-layer, with refractive index somewhat less than unity. This makes the radar ray to bend down slightly, which immediately gives a large area where the condition of perpendicularity can be fulfilled for reasonable low critical frequencies in the layer.

6. O. E. H. Rydbeck, H. Hvatum. — Radioastronomical observations during the solar eclipse, June 30, 1954 (in process of publication).
7. B.-A. Lindblad. — Combined visual and radar observations of meteors (research note for Boulder conference).
8. O. E. H. Rydbeck. — The propagation and reflexion of electromagnetic waves in streaming ionized media (with application to the ionosphere and the solar corona) (in course of publication).
9. O. E. H. Rydbeck. — On the theory of generation of excessive solar radio noise (in course of publication).
10. T. Orhaug, H. Hvatum. — Observations of radio star scintillation at high latitudes (in course of publication).

Summary : Observations on radio star scintillation at the Chalmers Radio Wave Propagation Observatory, Gothenburg, on 33 Mc/s and 150 Mc/s have shown a large variation in scintillation rate dependent on sidereal time (rate-step). This rate-step has only been observed on 33 Mc/s. A specimen of a scintillation record on 33 Mc/s showing rate-step phenomenon is included.

11. Staff reports to the Swedish 1957 radio scientific conference : Isophoto measurements at the Onsola observatory on 150 and 33 Mc/s ; scintillation measurements on 150 and 33 Mc/s ; hydrogen line observations on 21 cm.

Switzerland

N° 142. — Report of the Swiss National Committee to Commission V

Prof. Waldmeier

With regard to the solar radioelectric emission, the Federal Astronomical Observatory at Zürich has given all his attention to the following points :

1. The plan of the creation of a radioastronomical station has been carried on. It is foreseen to register permanently the solar radioelectric emission in three well determined frequencies. In addition to this programme an investigation of the solar radioelectric spectrum will be undertaken.

2. The following table gives the list of the stations registering permanently the solar radioelectric emission, as well as the frequencies of measurements.

Observatory	Frequency MH/s
Cavendish Laboratory, Cambridge, England	81, 175
Cornell University, Ithaca, N. Y., U. S. A.	200
Research Institute of Atmospherics, Nagoya University, Toyokawa, Japan	3750
National Bureau of Standarts, Central Radio, Propagation Laboratory, Boulder, Colorado, U. S. A. ..	460
Observing Station Nederhorst den Berg, Radio (Nera)	200, 545
Institute for Teoretisk Astrofysikk, Universitetet, Blindern, Oslo, Norway	200
National Research Council, Ottawa, Canada	2800
Radio Physics Laboratory, Sydney, Australia	62, 98, 200
Tokyo Astronomical Observatory, Mitaka, Tokyo ...	200, 30

The observations are collected by the Radio Physics Laboratory at Sydney and then published by the Federal Astronomical Observatory in the « *Quarterly Bulletin on Solar Activity* » together with the optical datas.

These publications relate on :

(*a*) Total intensity of the radiation,

(*b*) State of polarisation,

(*c*) Variability of radiation,

(*d*) Special phenomena (eruptions),

(*e*) Spectral classification of the solar activity.

The bulletins N° 101 to 112 have been published, including the period from January 1953 to December 1955.

3. The following were issued :

M. WALDMEIER : Die Variation der solaren radiofrequenten Strahlung bei 10, 7 cm im 11 järigen Zyklus. Astron. Mitt. Eidg. Sternwarte Zürich N° 190 (*Zs. f. Astrophysik* 36, 181, 1955).

M. MULLER : Ueber die Randverdunkelung der radiofrequenten Sonnenstrahlung, Astron. Mitt. Eidg. Sternwarte Zürich N° 198 (*Zs. f. Astrophysik* 39, 160, 1956).

United Kingdom

N° 128. — Report on British Work carried out in Radio Astronomy since 1954

by A. C. B. LOVELL

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X. Radio observations of aurorae.

XI. Radio observations of the moon :

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XII. Radio observations of the planets.

References.

I. — Introduction

This report summarises the work in Radio Astronomy which has been carried out in Great Britain since that reported to the XIth General Assembly in 1954. The observations have been made at the Cavendish Laboratory, Cambridge the Jodrell Bank Experimental Station of the University of Manchester and the Radar Research Establishment of the Ministry of Supply, Malvern.

II. — Radiation from the sun

(*a*) *Routine observations*

Regular observations of the intensity of the radio emission from the sun have been maintained on wavelengths of 1.7, 3.7 and 7.9 m, and the results have been communicated to the *Quarterly Bulletin of Solar Activity.*

(*b*) *The distribution of radio « brightness » across the solar disk*

A new series of measurements has been made during the period of minimum solar activity, to find the distribution of radio « brightness » across the undisturbed solar disk. The measurements were made at wavelengths of 60 cm, 1.4 m, 3.7 m, and 7.9 m, and in each case an interferometer of variable spacing was used. In some of the measurements it was possible to vary the axis of the interferometer in order to obtain the complete two-dimensional distribution (Conway and O'Brien, 1956); at other wavelengths information on the departure from circular symmetry was derived from measurements made at the eclipse of 1954 June 30 (O'Brien and Tandberg-Hanssen, 1955).

The present results suggest that the coronal temperature remains constant at 10^6 deg. K ($\pm$ 25 %) down to the corona-chromosphere boundary. The form of the limb-brightoning observed at 60 cms indicates that the electron density at the boundary has a value of $(1.5 \pm 0.5) \times 10^9$ cm^{-3}, and that the scale height is of the order of 2000 km (Conway, 1956*c*).

(*c*) *An attempt to measure the general magnetic field at coronal levels*

The presence of a general magnetic field would produce a small circularly polarized component in the radiation emitted from the corona; the sense would be opposite for the two hemispheres. An earlier attempt to detect this component by observation during a partial eclipse was made by Christiansen, Yabsley and Mills (1949).

A more sensitive method has been developed in which an interferometric polarimeter was used consisting of two aerials with opposite polarization whose spacing could be varied along a North-South line. At a spacing of about 100 λ the contributions of opposite polarity from the North and South hemispheres combine to produce a deflection at the output of a phase-switching receiver (Conway, 1956*a*).

Using this instrument an upper limit of 0.25 per cent could be determined for the polarized component. The derivation of the magnetic field corresponding to this degree of polarization depends on the temperature and density in the lower corona, and on the assumed form of the magnetic field; a preliminary

estimate based on a dipole field leads to an upper limit of 1.0 for the surface field at the poles (Conway, 1956c).

(*d*) *The structure of the outermost layers of the corona*

Observations of the Crab Nebula when it is viewed through the outer regions of the solar corona have been continued and extended. Interferometric measurements carried out in 1954, 1955 and 1956 have confirmed the previous conclusions (Hewish, 1955) that the reduction of apparent intensity is due to multiple scattering of the radiation by coronal irregularities whose scale lies in the range 2 km to 10^5 km. The magnitude of the scattering has shown a tendency to increase with the solar cycle, the greatest effect being observed in 1956. The scattering observed at the same angular distance, but on opposite sides of the Sun, has exhibited systematic differences which may be explained if the irregularities are more widely distributed in the equatorial direction than toward the poles.

Observations made in 1956 with two similar interferometers orientated perpendicularly suggest that the scattering is anisotropic, as would be expected if the irregularities were filamentary and orientated by a magnetic field. There is also evidence for refraction phenomena at angular distances smaller than 7 solar radii when the Crab Nebula is viewed through the corona in the vicinity of the pole (Hewish, in preparation).

(*e*) *Solar radio eclipse observations*

Measurements at a wavelength of 10.5 cm in 1954 June 30 of the partially eclipsed Sun observed from a site near Malvern have been reported by Hey and Hughes (1956). As the path of the moon across the Sun was inclined with respect to the solar equator, any departure from circular symmetry in the radio brightness distribution would become apparent in a partial eclipse as a difference in the shape of the two halves of the curve of received intensity. Such a difference was observed on the radiometer and this could be explained by a slight ellipticity in the brightness distribution with greatest extent in the equatorial plane. It was concluded that the departure from circular symmetry known to occur in the corona also extends down into the

chromosphere. The form of the eclipse curve also indicated limb brightening, as expected.

Previous observations of solar radio eclipses have been summarised in a review by Hey (1955).

(*f*) *Analysis of solar radio bursts*

An analysis of the distribution in longitude from central meridian of flares associated with radio bursts at $\lambda = 4.1$ m during 1946-51 has been made by Hey and Hughes (1955). This has confirmed that radio bursts are more frequently associated with flares on the eastern half of the solar disk than on the West. In order to determine whether or not the asymmetry could be attributed to absorption in solar corpuscular streams a detailed analysis was made for the years 1947-50 inclusive to find how the asymmetry was related to geomagnetic activity. It was found that the flare-active solar regions responsible for the occurence of high magnetic character figures were also regions which were predominant in producing radio bursts. Although the regions associated with high geomagnetic activity showed a dip in the numbers of associated radio bursts near central meridian, and this might be due to absorption in corpuscular stream emission, the East-West asymmetry appeared to be a more general effect. It was suggested that the explanation is that in general there is an East-West asymmetry in the solar atmosphere in the vicinity of flare-active solar regions, and that the asymmetry in the received radio emission is caused by absorption and refraction in the solar atmosphere above the flares.

The asymmetry in the numbers of flares observed in Hα is also discussed, and it is shown that in a similar way this could be explained in terms of absorption in the solar atmosphere. Whereas the radio results suggest an asymmetrical East-West structure in the lower corona, the distribution of flares in Hα also indicates that the asymmetry in structure probably extends down to the corona.

III. — Extra-terrestrial radio frequency radiation

(*a*) *Surveys of radio sources and their identification with optical objects*

The large interferometric radio telescope completed in Cambridge early in 1953 (Ryle and Hewish, 1955) has been used for a survey

of radio stars at a wavelength of 3.7 m (Shakeshaft, Ryle, Baldwin, Elsmore and Thomson, 1955). 1936 sources were located in the area of sky between declination $+83^{\circ}$ and -38°. Most of these sources were of small angular size ($<10'$) but some 30 sources had angular diameters lying in the range $20' - 180'$.

A comparison of the positions of the radio sources found in this survey with those of various classes of optical objects was made and radio sources were found corresponding to the remnants of the supernovae of both Kepler and Tycho, and to the nearby extragalactic nebulae M. 31 and M. 51. Two of the sources of large diameter were identified with the emission nebulosity IC. 443 and one of a similar nature in Auriga. An examination by Dr. Minkowski of 48 in. — Schmidt plates containing 75 of the most accurately determined positions has revealed no significant coincidences with optical objects.

The discrete sources in the field of view of the fixed 218 ft paraboloid at Jodrell Bank have been surveyed at a wavelength of 3.2 m. In this survey the paraboloid was used to make total power records with a beamwidth of about 3 degrees and, simultaneously, it was used as one component of an interferometer with a baseline of about 150 wavelengths. A careful comparison of these two sets of records is being made to test for significant discrepancies in the results obtained by the two different techniques ; it is hoped that this work will be helpful in assessing the limitations of various methods of surveying the sources. The survey is complete but the results have not yet been fully analysed.

Observations with the 218 ft fixed paraboloid have shown that there is an intense source of large angular diameter approximately in the position of the Great Loop in Cygnus, a tentative identification has been proposed (Walsh and Hanbury Brown, 1955). An alternative identification of the discrete source (17S2A) has been suggested by Davies and Williams (1955), also Davies (1956). They have suggested that the source is associated with an ionized hydrogen region at a distance of 3 Kpc from the Sun rather than with the galactic nucleus.

(*b*) *The distribution of radio sources*

The sources observed in the Cambridge survey were divided into two classes on the basis of their angular size and their distri-

butions over the sky plotted separately. The sources having angular diameters $> 20'$ showed a strong concentration towards the galactic plane ; the sources of small angular size were distributed isotropically.

An analysis of the number-density relationship of the latter sources showed that they could not be accounted for in terms of a uniform spatial distribution ; there appeared to be an excess of faint sources. Since an effect of this type might be introduced by the « confusion » between weak sources on the record, a new method of analysis was employed which does not involve the interpretation of the experimental records in terms of individual sources (Scheuer, 1957). In this method the amplitude of the interference pattern is read at equal intervals of time and the probability distribution of the record amplitude is derived. This distribution may then be compared with that derived theoretically for a uniform, or any other, model of the spatial distribution of radio sources.

An analysis of this kind of the 3.7 m results showed that they were not consistent with a uniform distribution of sources (Ryle and Scheuer, 1955). It was suggested that this non-uniformity in the distribution of sources might be associated with the large scale structure of the Universe.

More recently, another survey has been made at Cambridge both to extend and check the results of the previous survey. The large interferometer has been modified for use at a wavelength of 1.9 m, providing a fourfold increase in the resolving power of the individual elements. The positional accuracy of the brighter sources is also improved by a factor of 2 in each co-ordinate compared with the survey at 3.7 m. This should prove of considerable importance in the search for optical objects associated with radio sources. The observations have been completed over a large area of sky and the reduction of the records is in progress.

(*c*) *Spectra*

Further experiments have been made to détermine the absolute spectra of the four most intense sources (Adgie and Smith, 1956) ; observations were made at wavelengths of 60 cm, 1.4 m, 3.7 m and 7.9 m, using aerials of small directivity whose power gains could be calculated. The absolute sensitivity of the receivers,

was determined by calibrating with the noise power from a heated resistance.

A new series of observations of a larger number of sources at the extreme wavelengths of 60 cm and 7.9 m has been made by Conway (in preparation) and Whitfield (in preparation); in these observations aerials of greater directivity were employed and their gains were determined by observations of Cygnus A.

Whitfield has combined these new results together with those of all previous surveys to try to derive the most reliable spectra for a number of sources. Owing to the difficulties of absolute calibration many of these surveys cannot be regarded as giving absolute fluxes, although the relative fluxes of different sources may be of considerable accuracy. The fact that a number of absolute measurements of Cygnus A and Cassiopeia A are now available makes it possible to scale the fluxes quoted by a large number of observers to agree with the curve found for the two intense sources. Using a correction factor derived in this way, spectra have been derived for 26 sources, and for most of the sources the spectral curves appear to be remarkably smooth. Whitfield has also pointed out that the available data on Cassiopeia A are most easily fitted to a simple linear spectrum.

Measurements have been made of the intensities of the discrete sources in Cygnus (19N4A) and Cassiopeia (23N5A) at frequencies of 16.5, 19.0, 22.6 and 30.0 Mc/s using the 218 ft fixed paraboloid at Jodrell Bank (Lamden and Lovell, 1956). The main feature of the results is that the intensity of both sources falls abruptly at frequencies less than 22 Mc/s. An explanation of this phenomenon in terms of absorption in interstellar hydrogen is proposed.

(*d*) *Distribution of emission across radio sources*

Measurements of the distribution of brightness across M. 31 have been made at a wavelength of 3.7 m using sections of the large interferometer. (Baldwin, 1954). The radio emission was found to be distributed in a roughly spherical region surrounding the galaxy having a radius of 18 kpc.

Observations of the peculiar extragalactic nebula M. 87 were made using an interferometer having spacings up to 160 wavelengths (Baldwin and Smith, 1956). Faint extensions of the source were measured having a diameter of some 50′ of arc.

The intense radio source in the direction of the galactic centre has been observed at wavelengths of 60 cm, 1.4 m, 1.9 m, 3.7 m, and 7.9 m using the large radio telescope and smaller moving aerial systems (Smith, O'Brien and Baldwin, 1956). The size of the source was found to be closely similar at all these wavelengths. The brightness temperature of the source at low frequencies was considerably greater than 10 000 K and is not consistent with thermal radiation from an H II region. Interferometric observations of the intense sources in Cygnus and Cassiopeia were made at different spacings at a frequency of 500 Mc/s (Conway, 1956*b*). The visibility curve agreed very closely with observations made at lower frequencies (Smith, 1952; Jennison and Das Gupta, 1953) showing that the size of the sources varies little with frequency.

Earlier observations of the sources in Cygnus (19N4A) and Cassiopeia (23N5A), carried out with a post-detector correlation interferometer by Jennison and Das Gupta (1956), have been repeated by Jennison and Latham using a special type of interferometer which gives both the relative amplitude and phase of the fringe patterns recorded with different aerial spacings. One result of these observations is to confirm the model of the Cygnus source derived from the original measurements; in this model the source consists of two similar but separated radiating centres. A more precise value for the direction of the minor axis of the Cygnus source has been determined. The results of this work have not yet been published.

Preliminary measurements of the apparent angular diameter of the intense sources in Taurus (05N2A) and Cassiopeia (23N5A) have been made at a wavelength of 10.7 cms using an interferometer (Rowson, 1957). In the case of the Taurus source the angular distribution of intensity at 10.7 cms does not differ appreciably from the results obtained at metre wavelengths; in the case of the Cassiopeia source the angular diameter appears to be 10 or 20 per cent less than at metre wavelengths, although this latter result may not be significant.

The investigation of the angular diameter of the intense sources in the field of view of the 218 ft fixed paraboloid at Jodrell Bank at a wavelength of 1.9 m has been continued, attention being given to sources at high galactic latitudes. Details of five of these

sources have been given by Morris, Palmer and Thompson (1957). The principal interest of this work is that, of the five sources investigated, two had angular diameters of a few minutes of arc, while three could not be resolved and must have angular diameters of less than 12 seconds of arc. The three sources of very small angular diameter have brightness temperatures which are comparable with that of the Cygnus source, and it is suggested that they are probably also associated with colliding galaxies which may be too faint for optical identification.

(*e*) *Lunar occultations of radio sources*

The first lunar occultation of a radio source was made on April 26, 1955, when measurements were made at Cambridge of the extended radio source 2C.537 corresponding to the galactic nebulosity IC.443 (Elsmore and Whitfield, 1955). The form of the occultation curve at a wavelength of 3.7 m indicated that the radio emission was concentrated in the filaments showing strong Hα emission.

The occultation of the Crab Nebula was observed on 1956 January 24 at wavelengths of 3.7 m and 7.9 m (Costain, Elsmore and Whitfield, 1956); continuous records were obtained both at immersion and emersion and an accurate strip distribution of brightness across the source was derived at 3.7 m. The diameter was greater at 7.9 m than at 3.7 m. The position of the centre of the radio source calculated from these observations coincides very closely with that of the optical object, but there was no fine structure in the « brightness » at 3.7 m such as might be associated with the irregular features observed optically.

(*f*) *Polarization of the radio sources*

The radiation from three intense discrete sources in Cygnus (19N4A), Cassiopeia (23N5A) and Taurus (05N2A) has been tested for polarization at a wavelength of 1.9 m (Hanbury Brown, Palmer and Thompson, 1955). No evidence of plane or circular polarization was found. The source in Taurus (05N2A) was also examined for plane polarization at 1420 Mc/s (Davies, 1957), and it was found that any plane polarized component must have an intensity less than about 2.7 per cent of the total.

(*g*) *Survey of the background emission at* 3.7 *m*

One element of the Cambridge radio telescope has been used for a survey of the background radio emission at a wavelength of 3.7 m (Baldwin, 1955*a*). The area of sky between declinations $+80^{o}$ and -28^{o} was covered using a beam width of 2^{o} in right ascension and 15^{o} in declination. Values of the brightness temperature accurate to within 10 % were measured in regions away from the galactic plane.

(*h*) *Interpretation of the* 3.7 *m survey*

An analysis of the observed distribution of radio emission over the sky at 3.7 m has been made showing that most of the radiation at high galactic latitudes originates in a spherical region in the galaxy having a radius of 11-14 kpc inside which the emission per unit volume is remarkably constant (Baldwin, 1955*b*). This feature is very similar to that observed in M.31 and to the extended halo of M.87. It was possible to put an upper limit of 500^{o} K for the brightness of the integrated extragalactic emission at 3.7 m. Theoretical estimates of the magnitude of this radiation have been made by Shakeshaft (1954) who showed that its value was between 50^{o} K and 900^{o} K at a wavelength of 3 m, the result depending strongly on the cosmological theory assumed.

The distribution of radiation at galactic latitudes less than 30^{o} was found to be consistent with the model of the radio galaxy proposed by Westerhout and Oort (1951).

An examination has been made of the belt of emission which has been associated with the concentration of bright galaxies known as the Supergalaxy (Kraus and Ko, 1953 ; Hanbury Brown and Hazard, 1953). From the distribution of the emission and its intensity it has been concluded (Shakeshaft and Baldwin, in preparation) that the emission cannot be accounted for in terms of emission from individual galaxies. Furthermore, objects of this type distributed throughout space would provide an integrated extragalactic emission much greater than that observed. It is suggested that the radio emission may be a feature inside the galaxy.

(*i*) 7.9 *m and* 3.2 *m surveys of the background radiation*

A new technique has been used which has made possible a pencil-beam survey of the sky at 7.9 m with a resolution of about 3° (Blythe, in preparation). The survey map shows many discrete features including some previously unknown sources along the galactic plane, but it will probably be of greatest importance in its delineation of the general outline of the galactic plane itself, and of the emission at small distances from it. Radiation from the galactic halo is also clearly shown, but with a poorer accuracy.

A survey of the field of view of the 218 ft paraboloid at Jodrell Bank has been completed by Walsh and Hazard at a wavelength of 3.2 m. The results are at present being analysed.

(6) *Spectrum of the background radiation*

Adgie and Smith (1956) have made accurate measurements of the spectrum of the radiation received by simple broadside aerials with identical reception patterns at the three frequencies 38, 81.5 and 175 Mc/s. The receivers were calibrated against thermal loads. The aerials beam was arranged to sweep across the sky at a declination where the radiation from the galactic plane was easily distinguishable from the radiation from the halo. The spectra of all parts of the sky were found to be closely the same, except for a strip along the galactic plane where the effects of H II emission were noticeable.

Some account of the methods of calibration used in these measurements and in those of discrete sources mentioned in Section III (*c*) above will be given in a report to U.R.S.I. by Sub-Commission V (*d*).

IV. — Spectral line emissions

(*a*) 21 *cm line emission*

Continuing the work described in the previous report, the hydrogen line spectrometer at Jodrell Bank has been applied to the measurement of the distance of radio sources by observing the absorption of their radiation by interstellar neutral hydrogen (Williams and Davies, 1956). Observations have also been carried out of the 21 cm emission from neutral hydrogen in the

direction of dense interstellar dust clouds lying in the galactic plane. The emission in these directions is lower than in surrounding regions and appears to be due to dense H I clouds at a low kinetic temperature (Davies, 1956).

(*b*) *The* 91 *cm deuterium line*

Observations in the direction of the galactic centre have been made in an attempt to measure the intensity of the deuterium line in absorption (Adgie and Hey, 1957). The aerial was 24 ft in diameter and followed the direction of the galactic centre automatically. The receiver frequency was altered in steps of 10 kc/s over a total range of 100 kc/s, with an integration time of 5 minutes at each frequency. At the latitude of observation, the galactic centre was above the horizon only for a few hours daily, and four frequency sweeps were made each day. After rejection of results showing evidence of disturbances due to interference, and the application of corrections for the spectrum of the receiver noise, the results for 14 days were averaged and it was concluded that the deuterium line intensity must be less than 0.1 °K. From this it was deduced that abundance of deuterium does not exceed 1/2000 that of hydrogen. These results are thus not in agreement with those reported by Getmanzev, Stankevitch and Troitsky in 1955.

V. — Theoretical work on mechanisms

The radio emission from the haloes of the galaxy and of M.31 has been interpreted by Burbidge (1956) in terms of the acceleration of relativistic electrons in weak magnetic fields. From considerations of the stability of the interstellar gas away from the galactic plane a magnetic field close to 10^{-6} gauss was derived. The electrons responsible for the radio emission at 3.7 m have energies of about 1.5 Bev.

Adgie and Smith (1956) pointed out that the similarity of the spectrum of the emission from all parts of the galaxy except the H II regions, indicates that relativistic electrons circulate throughout the halo, and that a magnetic field extends through the halo with a strength of at least one fifth of that in the galactic plane. Since the magnetic filed close to the plane is believed

to be about 10^{-5} gauss, this estimate agrees well with that calculated by Burbidge.

The origin of the Class I sources has been discussed by Hanbury Brown (1954). He argues that the population of discrete sources which are observed to be in the galaxy at metre wavelengths may possibly be due to the remnants of supernova, and therefore there is no imperative necessity to invoke some unknown type of celestial body to explain these sources.

VI. — Investigation of the ionosphere by observations of radio stars

Observations of the scintillation of the Cassiopeia source have been continued in Cambridge at a wavelength of 7.9 m. Three interferometers triangularly situated and spaced by about 1 km have been used to investigate both the rate of drift and the shape of the autocorrelation function of the field distribution over the ground. It has been found that the diffraction pattern is considerably elongated and the direction of maximum elongation suggests that the F-region irregularities are extended along the lines of force of the terrestrial magnetic field (Spencer, 1955).

A comparison of monthly averages of the scintillation index from year to year has shown a significant decrease in the incidence of scintillations during the period of sunspot minimum, although the diurnal variation has remained substantially unchanged.

At Jodrell Bank the phenomena have been studied on 80 Mc/s by using an equatorially mounted aerial system which enabled the Cassiopeia scintillations to be recorded continuously, and also by three station triangulation measurements over a 1 km baseline on either Cassiopeia or Cygnus. The problems examined may be classified as follows : (*a*) the relation of the scintillation effects to other geophysical phenomena, (*b*) the origin of the irregularities in electron density which give rise to the diffraction effects, (*c*) relation with E region phenomena.

(*a*) *The relation of the scintillation effects to geophysical phenomena*

A study of the diurnal variations and associated geophysical relations has been made by Dagg (1957*a*, *b*) using an equatorially

mounted aerial system which enabled the Cassiopeia scintilations to be recorded continuously. The main results are as follows :

(i) *Occurrence of scintillation.* — The variation of the occurrence of scintillations shows a fairly rapid rise after 1800 to a peak about 2130 then a gradual fall to a minimum at about 0600 to 0800. The daytime occurrence is slight and shows no regularity. No marked seasonal variation is shown in the time of occurrence of scintillations.

(ii) *Amplitude of scintillations.* — The amplitude variation agrees in general with the variation in occurrence but the peak is more distinct. There is a seasonal variation in amplitude which corresponds with that of the magnetic activity.

(iii) *Rate of fluctuations.* — The fluctuation rate rises after 1800 to a peak at 2100, then falls steadily to a low value at 0400 after which the results are unreliable.

(iv) *Correlation with Spread F.* — Previous results showed that scintillations and spread F tended to occur on the same nights. The new results show that the peak of occurrence of scintillations is about 4 hours earlier than that of spread F and that the seasonal variation in spread F is not apparent in the radio star scintillation phenomena. Dagg suggests that the ionospheric irregularities responsible for both phenomena are produced by the same mechanism, but that blanketing by the F-region affects the observation of spread F although not the radio star scintillations at 80 Mc/s.

(v) *Correlation with magnetic activity.* — Further confirmation has been obtained of the close correlation between the drift velocities and the magnetic K-index, and it has been shown that the drift velocity varies linearly with field changes up to about 200γ after which the magnetic field increases more rapidly than the drift velocity. More detailed correlations of scintillation records with associated magnetograms have shown that :

(1) there is a close correlation between changes in fluctuation rate and changes in magnetic field, particularly changes in the ΔV component ;

(2) sometimes there is a very close correlation between fluctuation amplitude and magnetic field changes, but at other times there may be no correlation ;

(3) the fluctuation amplitude correlates more closely with the changes in the ΔH than with the changes in ΔV.

(vi) *Reversals in drift direction.* — Reversals in the drift direction are often observed near midnight, and an attempt has been made to correlate the time of reversal with the degree of magnetic disturbance. The occasions when reversals occur are found to be associated with marked magnetic disturbances, and there is a tendency for the time of reversal to be earlier in the night when the K-index is high.

(vii) *Scintillations during a solar eclipse.* — At the time of the total eclipse of the Sun on 1954 June 30 the line of sight from Jodrell Bank to Cassiopeia traversed the 400 km region within 150 km of the path of totality. At the time of the eclipse scintillations were observed, and it has been shown by Dagg (1956) that the two events were probably associated, the chance that scintillations would occur at that time of day being about 1 in 5.

(*b*) *The origin of the irregularities*

Maxwell (1954) suggested that the inhomogeneities responsible for the scintillation effects were caused by a turbulent wind effect in the upper F region, and that the absence of scintillations during the daytime might be due to the suppression of this turbulence by a large temperature gradient. However, it is now believed that any explanation involving bodily movement of the atmosphere at these heights must be abandoned. On the other hand there is abundant evidence that actual turbulence can occur in the 100 km region and thereby affect the dynamo region. Dagg (1957*c*) has suggested that the turbulent component of the electric field which is thereby generated will be communicated to the F-region along the earth's lines of force. There, the turbulent field will interact with the magnetic field and the turbulent component of velocity at the lower E-region level will be communicated to the F-region ionization. Dagg has shown that the main characteristics of the scintillation phenomena, including the magnetic relationships, can be explained in this way.

(*c*) *Relationships with E-region phenomena*

Although the evidence that the main scintillation phenomena arise in the F-region is regarded as very convincing, the workers

in Sydney have made suggestions that certain effects arise in the E region. Of interest in this connection is the discovery made by Dagg (1957*d*) of a very unusual form of scintillation occurring in the summer months. In these cases the peak-to-peak intensities vary by as much as 200 % although the mean intensity of the source remains constant to within 3 %. The occurrence of these « radio star ridges » shows a high correlation with sporadic E and it is suggested that the sporadic E clouds of ionization act as a diverging lens.

VII. — New techniques

(*a*) *The 250 ft steerable radio telescope*

The construction of the 250 ft aperture steerable radio telescope which was started in 1952 is nearly complete, and the instrument is expected to come into operation during the summer or early autumn of 1957. The main engineering and scientific characteristics of the instrument together with the proposals for the initial research programmes have been described by Lovell (1956).

(*b*) *Calibration of a standard noise source for 10 cm radiometers*

To provide a standard temperature noise source for use with radiometers, Hughes (1956) has made an absolute calibration of the argon discharge tube CV1881. With the aid of a calibrated attenuator the effective temperature of the discharge tube at a wavelength of 10.5 cm was determined, by comparison with a hot load, with an error less than 0.1 *d*B. At the time of the eclipse of 1954 June 30, the discharge tube connected to a horn was used as an external source for comparison with the radiation received from the Sun. The apparent disk temperature of the uneclipsed Sun derived in this way was found to be 4.2×10^4 deg.K.

(*c*) *A new type of « pencil beam » aerial*

In order to investigate the structure of the galactic background at a wavelength of 7.9 m a new technique has been employed to produce a pencil beam whose width, to half power, is 3° (Blythe, in preparation). The instrument consists of a linear array of dipoles of length 1,200 ft in an east-west direction which was used in conjunction with a single element which could be moved

south along a perpendicular line from the centre of the array. Successive scans of the sky were made, moving the small element in steps of half a wavelength along the north-south line. The different records were added vectorially utilising the EDSAC digital computer with appropriate phases and weighting factors, to give a map of the sky with a resolution comparable to that of a rectangular aperture 600 ft in width. The system can be shown to be equivalent, both in sensitivity and observing time to a Mills' cross type of interferometer consisting of two perpendicular arrays of length 1,200 ft.

(*d*) *The technique of interferometers*

A discussion of the theory of the « post-detector correlation » or « intensity » interferometer, as applied to radio astronomy, has been published by Hanbury Brown and Twiss (1954). The same principle has been demonstrated in the laboratory with light, and a stellar « intensity » interferometer has been used to measure the apparent angular diameter of Sirius (Hanbury Brown and Twiss, 1956 *a*, *b*, *c*). A description of the « rotating-lobe » interferometer has been given by Hanbury Brown, Palmer and Thompson (1955*b*), and this instrument has been successfully employed on several discrete sources using a resolving power of about 15 seconds of arc.

VIII. — Meteor astronomy

(*a*) *The continuous meteor survey*

Continuous observations of meteor activity have been maintained at Jodrell Bank using the radiant survey apparatus with two fixed aerial beams, and a rotating aerail equipment surveying the sky twice per minute. The results of the observations on the day and night time meteor showers up to 1955 August have been given by Davidson (1956), but the subsequent surveys have not been published. The activity, velocities and orbital data of the well known streams are generally similar to those observed previously. The Geminid stream of 1954 was an exception. This showed unusual activity amounting to a 50 % increase over previous years, and the rate remained at an enhanced level in

1955 and 1956. The survey apparatus revealed a new shower with a radiant in Bootes, active between 16-19 January 1957. The activity was about 30 per hour — an increase of 5 times over the normal sporadic rate with the apparatus in question. An investigation of the records obtained over this period in previous years shows that similar activity occurred in January 1951.

Davies and Lovell (1955) have published the detailed account of the observations of the Giacobinid meteor stream during the day time on 1952 October 9 and have considered the factors which influence the occurrence of a shower from this comet. It was suggested that the results can be explained if perturbations have increased the perihelion distance of the meteors in front of the comet relative to those behind, and the possibility of future occurrences of the meteor shower is analysed.

(*b*) *Radio echo measurements of individual meteor orbits*

The 3 station radio echo technique for the measurement of the orbits of individual meteors has been described by Davies and Gill (1956) together with the account of the test of the system on the Geminid meteor shower. This apparatus, which can determine 200 individual orbits per day, has been applied to the sporadic meteor problem and to the investigation of the orbits of certain showers with the following results.

(i) *Sporadic meteor orbits.* — 2400 sporadic meteor orbits have so far been analysed in the magnitude range +7 to +8. The distribution of these orbits is most unusual. 50 % are concentrated within $\pm 15^{\circ}$ of the ecliptic. An additional 15 % move in nearly circular orbits with inclinations grouped around 60° and 120°. A further analysis of the sporadic meteors in the magnitude range +4 to +6 shows that this class of orbit becomes relatively less prominent and the results for these brighter meteors are more comparable with the photographic meteor results. The cosmological reason for the change in distribution of orbits is not, at present, understood. The results, in any case, entirely confirm the previous statistical experiments which showed that no hyperbolic orbits existed amongst the sporadic meteor population.

(ii) *The orbits of the η-Aquarids, Orionids, December Ursids and Giacobinids.* — The 3 station apparatus has been used to study the orbit of the η-Aquarid meteor stream active in early May. The orbits of 50 η-Aquarid meteors have so far been computed and the agreement with the orbit of Halley's Comet is confirmed. The results on the Orionid stream of October are in process of analysis. It is hoped thereby to settle the discussion as to whether the η-Aquarid and Orionid streams are the result of the passage of the earth through the orbit of Halley's Comet before and after perihelion.

The new meteor shower with a radiant in Ursa Minor discovered by the observers in Czechoslovakia on December 22, 1945 has been investigated systematically by the radio echo technique since 1948. Evidence has accumulated that the orbit of this shower is similar to that of Comet Tuttle 1939*k* but precise orbital data have been difficult to obtain because of the low activity of the shower. The 3 station apparatus is now being applied to the problem and the data are in process of analysis.

An investigation during the epoch of the Giacobinid shower in 1956 October gave two orbits definitely associated with the meteor stream. In view of the separation of the earth and the comet this result is unexpected.

(*c*) *The time distribution of meteors*

From time to time suggestions are made that meteoric particles enter the atmosphere in clusters or groups — quite apart from the large scale grouping associated with showers. A statistical analysis of certain selected radio echo results obtained over a number of years in various magnitude ranges has now been completed by Davies and Bowden (1957). They investigated 3000 occurrences and and no evidence of clustering or grouping.

IX. — Meteor physics

A review of the current situation in this field has been published by Lovell (1957) under the title « Geophysical Aspects of Meteors ».

(*a*) *Scattering of radio waves by meteor trails*

The results of the investigation of the polarization effects in the radio echoes from meteor trails have been published by Billam

and Browne (1955, 1956). The experiment was carried out in order to test the theoretical estimates made by Kaiser and Closs (1952) of plasma resonance effects. The results are in good agreement with the predictions namely (i) for short duration echoes which occur when the radio wave penetrates the ionized column (line density less than 10^{12} electrons cm^{-1}) plasma resonance is observed when the electric vector is transverse to the ionized colum but not when it is longitudinal. The polarization ratios are double those predicted by the theory but it is shown that this can be accounted for by the finite velocity of the meteor; (ii) for long duration echoes which occur when the radio wave cannot penetrate the ionized column (line density greater than 10^{12} electrons cm^{-1}), the reflection coefficient is independent of the polarization of the incident wave. It was also found that the variation of echo amplitude and duration for the long duration echoes was in general agreement with the theory except that the durations were somewhat shorter than expected. This is explained by the effect of turbulence minimising the effective diffusivity. In the transition case when the line density is 10^{12} electrons cm^{-1} the observations sometimes showed high polarization ratios of about 3, which increased towards the end of the echo. Although the Kaiser and Closs theory does not treat this transition case rigorously the result would not be expected from the extrapolation of the under-dense and over-dense cases.

An implication of the above theory is that for a trail which is initially overdense and subsequently diffuses so that the trail passes through the resonant condition with the line density at 10^{12} electrons cm^{-1} the radio echo should undergo a phase reversal of 180°. This reversal should be observed only for cases where the electric vector is transverse to the trail. This has been investigated experimentally by Greenhow and Neufeld (1956*a*) who distinguish this phase change effect from the phase changes introduced by the Fresnel diffraction and those arising because of the motion of the trail under wind forces. The results are in good agreement with the predictions of the Kaiser-Closs theory.

The effects of wind-sheer on the scattering of radio waves from an ionized column have been discussed by Kaiser (1955*a*). This effect is of particular practical importance in the determination of trail direction by the three station orbit apparatus referred to in Section VIII.

(b) Almospheric pressures and scale heights

Reference was made in the previous report to the work of Kaiser (1954*a*, *b*) and of Evans (1954) on the distribution of meteor heights, leading to a new technique for the determination of pressure and scale height in the meteor region. This work has been continued (Evans, 1955). The results do not differ significantly from those obtained by the rocket and photographic meteor techniques in New Mexico and geographical variations therefore appear to be small. Seasonal variations in the height of a given pressure level are of the order of ± 1 km which is little greater than the probable error. Possible diurnal variations with an amplitude of about ± 1 km have been found. The apparatus has been redesigned in order to investigate in more detail these seasonal and diurnal effects.

(c) Meteor mass distributions

A study of the magnitude and mass distributions of the sporadic and certain shower meteors has been made by using three radio echo methods (Browne, Bullough, Evans and Kaiser, 1956) : (1) observation of the total echo rate of short duration echoes, (2) observation of the height distribution of homogeneous velocity groups, (3) distribution of long duration echoes. For sporadic meteors the mass distribution is found to be an inverse square law over the magnitude range 0 to +10. The mass distribution of the daytime Arietid shower can be represented by an inverse power law with an exponent greater than 2, indicating that the faint meteors are most plentiful. In the case of the Perseids, Quadrantids and Geminids the exponent is less than 2 for the faint meteors. This result indicates that the main contribution to the meteoric mass in these three showers comes from meteors in the magnitude range +2 to +5.

(d) Meteor ionization

Preliminary studies of the meteor ionizing and luminous efficiencies have been made by simultaneous visual and radio observations (Evans and Hall, 1955). The ratio of the efficiencies appears to be almost independent of velocity. There is evidence that the ionizing efficiency approaches unity and has only a small

velocity dependence. Work is now in progress on a combined radio echo and photographic programme using specially constructed Schmidt meteor cameras, from which it is hoped to obtain more precise results over a wide range of meteor velocities.

Kaiser (1953*b*) has investigated in considerable detail the question of the incident flux of meteors and the total meteoric ionization. He has deduced the meteoric ionization contribution from the radio echo measurements of line densities without introducing the somewhat uncertain factor of the ionizing efficiency. He concludes that sporadic meteors should produce 2.3×10^{-4} electrons/c.c./sec independent of height. The significance of this contribution to the E-region ionization depends on the value to be assigned to the recombination coefficient. If the normal E region value of 10^{-8} applies then the equilibrium electron density will be about 150 electrons/c.c. On the other hand the recombination rate in meteor trails is believed to be only 10^{-11} or 10^{-12} and if this value applies then the equilibrium electron density will be 10^4 electrons/c.c. The general effect will be to produce a continuum of ionization from about 130 to 115 km, but below this height the individual trails will not join up to form a continuum. If the recombination rate is near the lower value quoted above then the sporadic meteor ionization may be a significant factor in the maintenance of the nocturnal E region. As applied to the showers, the calculations show that the intense daytime streams will not make a significant contribution to the summer daytime E-region ionization. The major night time showers will make a contribution similar to that of the sporadic meteors but at a lower height (e.g., 100 km for the Perseids and 93 km for the Geminids).

(*e*) *Diffusion coefficients*

Previous considerations have indicated that diffusion processes, as distinct from recombination and attachment, are mainly responsible for the dispersal of the ionized matter in a meteor trail. The coefficient of diffusion as a function of height has now been measured by Greenhow and Neufeld (1955*a*). They restricted their measurements to trails for which the line density was less than 10^{12} electrons cm^{-1} in which case the duration is a function only of the wavelength and diffusion coefficient D.

The split beam technique was used for the height measurements. The results apply to the height range of 80 to 110 km for which D varies from 10^4 cm^2/sec at 80 km to 10^5 cm^2/sec at 100 km. These values are very close to the theoretical calculations, using the rocket panel values for the air densities in this height range.

(f) The variation of ionization along a meteor trail

The light curves for meteors have been found to show good agreement with the theoretical curves for bright meteors in the magnitude range 0 to −7. On the other hand recent work at Harvard has shown that for fainter meteors down to magnitude +3 there are serious anomalies which have been explained in terms of fragmentation of the meteoric particle. Hitherto it has been assumed that the variation of ionization along the trail follows the theoretical curve, but in view of the anomalous photographic results Greenhow and Neufeld (1957) have investigated the ionization curves experimentally. The technique consisted of the observation of the radio echoes from the same trail at two widely spaced stations. The results show that the mean ionization curves for faint meteors in the magnitude range +6 to +8 are much shorter than predicted by theory and that the rise to maximum electron line density is more rapid than expected. Evidence is obtained that individual meteors may depart considerably from this mean curve -- for example in some cases the electron density increases from zero to its maximum value in a trail length of less than 800 m. Evidence for fragmentation and irregular ionization is also obtained and, in general, the anomalous behaviour is similar to that of the light curve.

(g) Upper atmospheric winds determined by the meteor technique

The work on wind measurements in the 80 to 100 km region reported previously (Greenhow, 1952) used a pulse technique. This technique has been abandoned in favour of a combination of a pulse and continuous wave method in which the data rates are high enough for a study of the diurnal variations (Greenhow, 1954). This coherent pulse technique yields over 3000 usable echoes daily and a wind determination can be made from less than one hours observations. The method has been used for

a systematic study of these high altitude winds since 1953 and some of the early results have been published by Greenhow and Neufeld (1955*b*). The results for a typical day show the wind reaching 40 m/sec with a semidiurnal variation and a phase difference of 3 hours between the N-S, E-W components, indicating a wind vector rotating in a clockwise direction with a period of 12 hours. The wind vector is towards the N at 06h and 18h except during the autumn months when the phase of the periodic wind component changes by 360°. The prevailing component is towards the N in winter and towards the S in summer. The prevailing E-W components are stronger and are towards the E in winter and summer and towards the W in spring and autumn. These results refer to a mean height of between 90 and 95 km. Recently the height variation of these winds has been studied (Greenhow and Neufeld, 1956*b*), and marked changes in phase and amplitude of the semidiurnal component are found over the height range of 80 to 100 km. The average phase change is about 5 degrees/km and the increase in amplitude with height about 1 m/sec/km. The prevailing wind also increases in strength with height to the extent of about 0.5 m/sec/km. The E-W component at 100 km blows towards the W during the summer and autumn but at 85 km this component remains towards the E during the autumn. It is shown that the variations in amplitude and phase are compatible with the theory that these winds are the result of thermal and tidal effects of the sun, increased by resonance at the heights under discussion.

The turbulent effects in this region have also been investigated. The mean wind shear is found to be 10 m/sec/km with 10 % exceeding 50 m/sec/km in the 80 to 100 km region. The scale of the eddies is about 7 km.

X. — Radio observations of aurorae

Radio echo observations of aurorae have continued at Jodrell Bank on a frequency of 70 Mc/s using two equipments. One equipment uses a low elevation pencil beam aerial which rotates continuously about a vertical axis sweeping the whole sky twice per minute. This has been in regular use since March 1953. The other equipement is the fixed beam apparatus primarily in use for the meteor radiant survey. A description of this work

has been given in two papers by Bullough and Kaiser (1954, 1955) and by Bullough, Davidson, Kaiser and Watkins (1957). Some of the principal results may be summarised as follows :

(i) The radio echoes are obtained by direct reflection from ionized regions which follow closely parallels of geomagnetic latitude. The ionized arc is very extensive, certainly exceeding 1000 km in extent and this estimate may be limited by geometrical factors so that the real extent may be much greater,

(ii) Most of the cases of reflection studied at Jodrell Bank occur from auroral ionization in a very narrow height range of about 10 km centred at above 125 km altitude,

(iii) With regard to the actual reflection process it is believed that this originates from a distribution of blobs of ionization of density greater than the critical value. Evidence is obtained that the blobs may be spherical with diameters less than 1 km and with electron densities of the order of 6×10^7 to 2×10^4 electrons/c.c.,

(iv) The echoes move in range at high velocity and there is a marked diurnal variation. The results average over a number of years show that the echoing centre has a mean receding velocity of 500 m/sec at 1800 U. T. passing through zero velocity between 2100 and 2200 U. T., and an approaching velocity of 500 m/sec at 0600 U. T. Individual centres move with velocities up to 3 km/sec. If as suggested in (i) the ionization is along a parallel of latitude, these receding and approaching velocities can be interpreted in terms of east-west, and west-east movements. These motions, which are in good agreement with the photographic results, are believed to represent a redistribution of the ionization and not a wind movement — since wind drifts determined at the same time by radio echo meteor techniques (see Section IX) show very much lower velocities of about one tenth of these auroral velocities,

(v) The diurnal change in drift motion is associated with a similar asymmetry in the disturbance of the vertical component of the earth's magnetic field,

(vi) There is a close correlation between visual aurora and the radio echoes, but the radio echo occurrence shows peaks at 1800 U.T. and 0200 U.T. and a minimum at the time of crossover of the

velocity motion (iv) and magnetic disturbance (v), i.e. between 2100 and 2200. The visual records show a single maximum between 2100 and 2200. A possible explanation is that the excitation process for visual aurorae is inefficient except when the source of excitation is pratically stationary,

(vii) This change is associated with a change in echo pattern: the diffuse echoes predominate in the evening sequence and the discrete echoes in the early morning sequence,

(viii) Another effect associated with this diurnal change is observed in the drift determination using the radio star scintillation technique (Section VI). From Jodrell Bank the line of sight to the radio source in Cygnus near lower culmination passes through the auroral zone. The drift directions between 0900 and 2100 U.T. are towards the west but there is a change in the preferred direction between 2100 U.T. and 0600 U.T. to the south west or south east. Since these diffraction effects occur in the F-region, this provides further evidence for the coupling effect suggested by Dagg (Section VI).

XI. — Radio observations of the moon

(*a*) *The lunar atmosphere*

The observations of the lunar occultation of IC.443 and the Crab Nebula have been used to deduce the density of the ionized lunar atmosphere by measuring the refraction of radio waves passing through it. From the time of emersion of a bright filament in IC.443, an upper limit of 10^{-12} × density of the terrestrial atmosphere was calculated. The difference in the observed time of obscuration of the Crab Nebula from that calculated has indicated that the density of the lunar atmosphere at the surface of the Moon may be 10^{-13} of that of the terrestrial atmosphere, and must certainly be less than 5×10^{-13}.

(*b*) *Radio echo observations*

Systematic radio echo studies of the Moon have continued at Jodrell Bank on a frequency of 120 Mc/s and some accounts of the work have been published by Browne, Evans, Murray and Hargreaves (1956) and by Evans (1956). The rapid fading is

caused by the libration of the Moon. The correlation between successive echoes has been studied and it is shown how this can be used to give information about the scattering from the lunar surface. In the published work it is concluded that the Moon acts as a « uniformly bright » scatterer for radio waves but in recent experiments this conclusion has been shown to be erroneous. In fact the main scattering of the radio waves takes place from a small area on the visible hemisphere of the Moon with a radius of about one third of the Moon's radius.

With regard to the slow period fading (15-30 minutes) it has been shown previously (Murray and Hargreaves, 1954) that the effect is caused by a rotation of the plane of polarization as the radio wave traverses the ionosphere. This fading has now been studied on two closely spaced frequencies in order to derive the total electron content per sq.cm. along the line of sight from the Earth to the Moon. A comparison of the results with the ionospheric density distribution calculated from the normal critical frequency data assuming a parabolic distribution, indicates that there are 2 or 3 times more electrons above the maximum of the F 2 layer than below. The diurnal, seasonal and long period changes in this total electron content are now being studied.

XII. — Radio observations of the planets

Radio emission from Jupiter

After the discovery in the U. S. A. by Burke and Franklin (1955) of the radio waves from Jupiter at 22 Mc/s, a search was made for radiation at 38 and 81.5 Mc/s (Smith, 1955). On 81.5 Mc/s a special series of observations with the large interferometer detected no radiation greater than 3×10^{-26} watts . m^{-2} . $(c/s)^{-1}$. On 38 Mc/s previous interferometer records were searched : no radiation greater than 10^{-24} watts . m^{-2} . $(c/s)^{-1}$ was apparent. These observations make it clear that the radiation is much more strongly dependent on frequency than in the case of other sources.

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U. S. A.

AGASSIZ STATION RADIO ASTRONOMY PROJECT

HARVARD COLLEGE OBSERVATORY

Since the inception of the project until July 1956 observations were carried out using the 24′ radio telescope. From July 1956 the 60′ reflector has been used for all observations. The major programs under way at present are listed below.

Subject	Main Results	Status June 1957
1. Hydrogen in stellar associations. (*a*) Orion.	Continuation of 24′ observations. Evidence of asymmetrical mass distribution in the expanding region.	Observations in progress. Results of 24′ observations to appear in Ap. J.

Subject	Main Results	Status June 1957
(*b*) λ Orionis	Evidence of increase of density at edge of HII region and of expansion of shell.	Program completed and in process of publication.
(*c*) I Lacertae	Evidence of expansion of hydrogen around association and increase of density.	In progress.
2 Galactic structure of Monoceros, Ophiuchus and Cygnus regions.	Cygnus studies show perculiar absorption effects	Program completed, analysis in progress.
3. 21 cm absorption profiles of sources.	Cas A, Taurus A and Cyg A completed. Cyg A shows new absorption effects with a number of components. Other sources are also being studied.	Analysis in progress.
4. Hydrogen in galactic clusters.	Definite evidence of hydrogen in galactic clusters Pleiades, Praesepe, *h* and χ Persei, Coma Berenices as expected from theories of stellar evolution.	Observations of these clusters in progress.
5. Turbulence in interstellar medium.		In progress.
6. Observations of hydrogen in external galaxies.		
(*a*) M33, M31, M81 M51, M32.	M33 detected and shows large unexpected extension beyond optical diamater. M31 similar. Large extension also detected.	Preliminary results under publications in P.A.S.P. Observations continuing.
7. Observations of clusters of galaxies.		In progress.
8. Search for intergalactic matter.		In progress.

University of Alabama

Work in radio astronomy at the University of Alabama has been devoted almost entirely to solar studies at mm wavelengths, although some measurements have been made of lunar temperatures and atmospheric absorption in the same wavelength region. First observations of the Sun were made in December 1955 and the period from December 1955 to May 1956 was devoted to observation of the Sun and atmospheric attenuation measurements at 7.5 mm. These measurements indicate a solar temperature of 5 700° K and total vertical attenuation of 0.3 to 0.6 db, depending upon weather conditions.

At this time the radiometer was converted to operate at 6 mm and the same measurements were made at the new wavelength. The indicated solar temperature at this wavelength is 4 500° K, and the total vertical attenuation varied from 1.1 to 1.5 db on clear days and from 1.8 to 2.3 db on overcast days.

In July 1956 a program of observation of the Moon was begun. The precision of this work was not high since the radiometer was designed for optimum performance in solar measurements. A calibration procedure developed in our laboratory gives best results when the antenna temperature of the object being studied is of the same order of magnitude as the ambient temperature. This makes a relatively small antenna desirable for solar observation and requires a somewhat larger antenna for best performance on the Moon. A change of as much as 30 per cent in lunar temperature would have been detectable. No variation of this magnitude has been observed, either as a result of the changing phase of the moon or during the total eclipse of November 1956. Our results show a lunar temperature of about 150° K.

The solar observations, in a wavelength region where no other results in radio astronomy have been quoted, are consistent with a current model of the chromosphere. The absorption measurements are consistent in magnitude with those predicted by the Van Vleck theory of oxygen absorption. The absorption in clouds appears to be smaller than anticipated and it seems that the « window » extends to somewhat shorter wavelengths than previously believed.

Work now in progress includes solar measurements at other wavelengths between 6 and 8.5 mm, construction of a diode-type

radiometer for the 3 to 4 mm range, and construction of a lunar radiometer with a 5 ft. parabola.

National Bureau of Standards

Boulder Laboratories

Radio emission from Jupiter. — Radio observations of Jupiter have been obtained during the winters of 1955-56 and 1956-57 when Jupiter appeared in the night sky. The measurements were made with scaled interferometers at 18 and 20 Mc/s simultaneously. The fan-shaped antenna pattern permitted each night's recording to extend over more than a full rotation of the planet. Several sources, fixed with respect to each other, have remained active over several years, as shown by comparison with Shain's 1951 data. The period of rotation determined by these sources is about 10 seconds shorter than the rotation of the clouds (System II).

The angle of the permitted cone of radiation from Jupiter, controlled by the planet's ionosphere, decreases with increasing solar activity. This effect has yielded the regression of the ionization in Jupiter's ionosphere versus solar activity. A detailed investigation of the same effect for each longitude gives some indication of the latitudes of the individual sources.

The ratio of total activity at 20 Mc/s versus 18 Mc/s is only 0.6 or less. Pulses with durations of the order of 0.01 second have been observed on high-speed recordings.

Solar radio noise. — A continuous patrol of solar emission at 167 Mc/s and 460 Mc/s has been maintained from sunrise to sunset on virtually every day. Hourly calibrations of receiver sensitivity provide a consistent reference for flux values, over a dynamic range extending to several hundred times the flux from the quiet sun.

Immediate reports of outstanding events are used for forecasting of radio propagation conditions, and will be used to help in the declaration of « world days » during IGY. Three-hourly and daily flux medians and variability, as well as outstanding events, have been reported to the IAU and since October 1955 published in CRPL-F series, Part B.

Scintillations of radio stars. — Phase-switching interferometers have been constructed for operation at 53, 108, and 470 Mc/s. These have been designed to include servo-operated phase shifters which will track the apparent position of a discrete source. In this way continuous recordings of phase scintillations can be made, unaffected by amplitude variations. The immediate program for these instruments includes a determination of the frequency scaling law of phase scintillations, and a comparison of scintillation observations with other ionospheric observables. The instruments are expected to be in operation by August 1957.

Cornell University

At the Radio Observatory in Ithaca, a 200 mc solar patrol (flux and east-west burst position) has been continuously maintained, as a link in the World Chain Program of Sub-Commission V*a* of U.R.S.I. Reporting of ionospheric disturbances was begun in February 1957, utilizing fadeouts seen on a 5 mc WWV record.

At the Sacramento Peak Observatory, a 200 mc solar flux patrol was maintained until June 1955.

A study was made of the propagation of polarized radio waves in the corona and ionosphere, especially of the Faraday effect. The primary conclusions were that the polarization dispersion in the corona would be so large that very narrow bandwidths or high frequencies should be required to see linear polarizations, and that the rotation in the ionosphere would be on the order of 6 radians at 200 mc. Experiments to investigate these effects were proposed.

A correlation-type polarimeter for analyzing solar bursts was constructed and has been in preliminary operation since December 1956. This instrument was designed to investigate the polarization dispersion in the corona. At present a two-bandwidth experiment is being carried out, with the second bandwidth being in the polarimeter at the Tokyo Observatory. Simultaneous solar records will be made during the daylight overlap time for an interval around the summer solstice, 1957.

A theory of radio star scintillation, based on ionospheric turbulence, was proposed.

A precision three-element interferometer to measure radio star scintillation and refraction is being completed.

Mount Wilson and Palomar Observatories

Carnegie Institution of Washington
California Institute of Technology

1. Low noise-interference site found in Owens Valley, site development including power line, roads, water supply, workshop, lab and living quarters and antenna rail tracks complete.

2. Thirty-two foot pilot model reflector, equatorially mounted, in operation at Palomar for last year. Working on 21 cm line, mainly on survey of Galaxy between −30 and −55 declination.

3. Twenty-five Mc/s interferometer in operation at Owens Valley, working on scintillation of radio stars.

4. Design of two 90-foot diameter equatorially mounted reflectors accomplished and fabrication about to begin.

Naval Research Laboratory

Washington, D. C.

Hydrogen Line. — Absorption measurements have been used to arrive at tentative distances for radio sources Cassiopeia A, Hagen, Lilley and McClain (1955) and Sagittarius A, McClain (1955). In the case of Cassiopeia A, strong velocity correlation between absorption features and spiral arm emission indicates a distance in excess of 2.5 kpc. In the more complicated case of Sagittarius A, a probable distance of about 3 kpc is indicated using the Naval Research Laboratory 50-foot instrument. The red shift has been measured in the colliding pair Cygnus A by Lilley and McClain (1956) indicating a constancy of $\Delta\lambda/\lambda$ of at least 1 part in 5×10^5. Lilley (1955) has pointed out the advantages of large antennas in searching for additional spectral lines in absorption. The advantage is a direct result of the increase in antenna temperature of the radio source used for background radiation. McClain (1956) has pointed out the potential of large antennas for the measurement of the cosmological red shift on external systems and the detection of intergalactic hydrogen. In addition some of the stringent drive requirements which must be incorporated in large instruments to take full advantage of this potential are discussed. Lilley (1957) has discussed the types of radio astronomical measure-

ments which might be of interest to cosmology. In particular the red-shift distance problem was treated from the viewpoint of a 140-foot antenna. The computations showed that significant red-shift measurements of the Cygnus A type could be extended more than a factor of four beyond the current optical limit and therefore well into the range of using the red-shift distance relation to distinguish cosmological models.

18 *cm Line of OH.* — Barrett and Lilley (1957*a*) in considering the possibility of detection of the OH line have concluded that for electric dipole transitions the state temperature T_s which characterizes the population distribution may be seriously influenced by the radiation temperature of the surrounding environment T_r. This result suggests that electric dipole transitions may be more readily observed in absorption than in emission. Barrett and Lilley (1957*b*) obtained a negative result in a search for OH. Regions observed were : (1) the galactic center, (2) the galactic anticenter, (3) the exact direction of the Cassiopeia A source and (4) the Earth's atmosphere against the Sun as a background radiation source.

Solar Studies. — The solar eclipse of 30 June 1954 was observed at Oskarshamn, Sweden, by Gibson, Coates, and Hagen at 8.6 mm wavelength and the brightness distribution across the solar disk was determined. This brightness curve is essentially flat from the Sun's center out to a radius of 11 minutes of arc, dips slightly to a minimum at 14.5 minutes of arc, rises to a peak just outside the optical limb, and falls off rapidly beyond the peak. The flatness of the curve and the slight drop at 14.5 minutes are incompatible with prior models of the chromosphere.

An observational program was initiated by Coates (1957*a*) to investigate the problem at a much shorter wavelength, 4.3 mm. A sensitive radiometer was developed for this purpose and installed in a 10-foot paraboloid antenna. Repeated scans across the solar disk were made with a half-power beamwidth of 6.7 minutes of arc. The 4.3 mm brightness temperature was measured as $7000^{\circ} \pm 700^{\circ}$ K, and the brightness distribution was found to be essentially uniform over a disk one per cent larger than the visible disk.

A new chromosphere model containing spicules has been

constructed by Hagen (1956) to explain the limb and centre brightening found at 8 mm wavelength in the measurements with the 50 foot antenna and more precisely in the 1954 8-mm eclipse measurements. The model has been extended by Coates (1956*b*) to cover both the 8.6 and 3.4 mm wavelength data. In this model the spicules are cylindrical (1500 kilometers in diameter) with their bases at the photosphere and their heights ranging from 3000 to 18 000 km. The number of spicules decreases rapidly with increasing height. The spicules are distributed in angle the predominant radial direction. The interspicule gas is hot and the spicule gas is cool: the spicule temperature deduced from the millimeter wavelength observations is 6400° K.

The radiation from the Sun at 9.4 cm wavelength was recorded during the eclipse of 30 June 1954 by Mayer, Sloanaker and Hagen (in press) using an antenna with a pencil beam of 3.5 degrees half-intensity width. The measured variation in the radiation during the eclipse was transformed to a radial brightness distribution for the Sun under the assumption of circular symmetry. This brightness distribution agrees well with that predicted from the quiet sun theory under the same assumption. A re-distribution of a small part of the integrated radiation to the equatorial limb regions improves the agreement between the model and the experimental result.

Radio Sources. — Roman and Haddock (1956) have presented a model for nonthermal radio sources which offers an explanation for the apparent step in the spectrum in the region of 300 to 600 mc. Based on partial occultation of the source by associated HII regions the same model can explain several rather different source spectra with only minor adjustments.

The spectra for seven of the radio sources were extended to 3.15 cm wavelength by Haddock and McCullough (1955). Three emission nebulae, the three most intense nonthermal sources, and the galactic center were measured. It was pointed out that the source in the direction of the galactic center is probably thermal with two plausible distances, i.e., a Strömgren sphere at the center or an HII region at three kpc associated with a known OB group.

Radio radiation from the planets Venus, Mars, and Jupiter has been observed by Mayer, Sloanaker, and McCullough (1957) at 3.15 cm wavelength using the NRL 50-foot antenna. The

measured intensity of radiation from Mars and Jupiter is quite consistent with thermal radiation predicted from infrared observations. The measured intensity of radiation from Venus is greater than thermal radiation predicted from infrared observations.

A survey of radio sources has recently been completed by Roman and Yaplee at 440 mc. The results agree rather well with those of Seeger in Holland and tend to further substantiate the mixed thermal and nonthermal nature of 17S?A. The results will be published in the near future.

In an effort to learn more about the physics of planetary surfaces Grant and Yaplee (in press) have made extensive investigations of the back scattering from both land and sea surfaces near normal incidence. Surfaces ranging from classical scatters to those having a rather high specular component have been measured.

Measurements of the thermal radiation of the Moon have been made by Gibson (1957*a*) at a frequency near 35 kmc to investigate further the variation of the radio wavelength brightness temperature with lunar phase first observed by Piddington and Minnett at 24 kmc. The measurements show a complex rather than a sinusoidal variation with phase varying between 225° and 145° Kelvin. The lunar equatorial brightness distribution is found to vary in the expected manner and was in agreement with the form of the central brightness variation during a lunation. Observations of two lunar eclipses show that no measurable change in lunar radiation occurs during the few hours of an eclipse. Comparison of these results with calculations by Jaeger suggests a lunar surface composed of a layer of fine dust of very low thermal conductivity, the average depth of which is estimated at one inch or more.

In connection with the above work on the Moon, Gibson (1957*b*) has studied the incremental fractional atmospheric absorption as a function of height at wavelengths of 0.86, 1.8 and 3 centimeters. The equivalent temperature of the thermal self radiation of the atmosphere has been derived and expressions for the transmission coefficient in the radiation transfer equation were developed. Two experimental methods were used at 0.86 cm to determine atmospheric attenuation which were self-consistent and also consistent with the theoretical development. The equipment used in the above experiments has been described in detail by Gibson (1956).

The Ohio State University

Radio astronomy observations at Ohio State began in 1952 using a meridian transit antenna consisting of 48 helices mounted on a tiltable steel ground plane. By late 1953 the number of helices was increased to 96 with the ground plane measuring 160 feet long (east-west) by 22 feet wide. This antenna has a fan-beam about 1° wide in right ascension by 8° in declination at 250 megacycles. This antenna has been used by Prof. H. C. Ko for extensive studies of the background radiation at about 1.2 meters wavelength culminating in a detailed map of the radio sky. The antenna has also been used for investigations of numerous individual localized and extended sources. These investigations include a study of the radio brightness distribution across the Andromeda nebula, the radio position of the galactic nucleus, the magnitude distribution of radio sources, radiation from the Rosette nebula, and the distribution of galactic radio radiation.

An important phase of radio astronomy work at Ohio State has been the development of new antenna types for radio telescopes and studies of the characteristics and performance of radio telescope antennas. In particular a design has been under test and development which has great potentialities in the large aperture field. It is of the reflector type and incorporates a fixed standing paraboloid and a tiltable flat reflector with the ground acting as part of the antenna structure both electrically and mechanically. It is a wide band antenna that can be operated over a frequency range of 10 to 1 or more and provides a very large aperture area per unit cost. The design is especially well suited for background essentially a meridian transit instrument it can be arranged to track objects near the meridian for moderate intervals.

Downcoming celestial radio waves are deflected by the tiltable flat-sheet reflector into the paraboloid and thence to a horn or other antenna at the prime focus. The reflecting surface of both paraboloid and flat sheet consists of coarse mesh wire screen. The only moveable structure is the flat-sheet reflector. Since a flat surface can be very easily checked for any unevenness, it is not necessary that the tiltable reflector be a rigid structure. This results in a large saving in cost. The reflector is tilted by a number of independently operated truss members and the desired degree of flatness of the reflector obtained by adjusting them individually

while monitoring or observing the reflector for flatness with a small optical telescope set up near one end.

It is much more difficult to maintain tolerances on a curved surface such as a paraboloid, especially if it is moveable. This problem is avoided and the cost correspondingly reduced by making the paraboloid fixed. In this way the ground itself provides the principal mechanical support for the paraboloid and the amount of structure required to maintain the paraboloid tolerances is a minimum. Movement is required of only the simple flat reflector and only 65 degrees of tilt of this reflector are necessary to cover nearly all of the observable sky. By making the length of the paraboloid considerably greater than its height there is an additional large saving in cost since the expense of a structure is approximately proportional to the cube of its height. Furthermore, the lower overall height will make the telescope much less susceptible to interfering radio signals of terrestrial origin, since such signals increase greatly in strength with height above the ground.

The design has been extensively tested by means of a scale model measuring 12 feet across and operating at a wavelength of 1.25 centimeters. By the principle of similitude, patterns measured in this manner on a scale model can be made to duplicate those of a full-size system. Measured patterns and performance of the model were so satisfactory that the model was put into use as an actual radio telescope at 1.25 centimeters wavelength for solar and lunar observations. Specifically the model duplicates the performance of a telescope with parabolic reflector 700 feet long by 70 feet high operating at 70 centimeters wavelength. Through a grant from the National Science Foundation a prototype radio telescope of this design with parabola 360 feet long by 70 feet high is now under construction at the Ohio State-Ohio Wesleyan Radio Observatory. The antenna is designed to operate in the wavelength range from 20 centimeters to 10 meters. The engineering and construction on this antenna is being done by Ohio State University students.

In 1956 a 40-foot diameter equatorially mounted steerable parabolic dish antenna was completed and put into operation at Ohio State. This antenna, operating in the frequency range of 200 to 1000 megacycles, is being used for mapping of selected

sky regions, such as in Cygnus, at 900 megacycles and also for studies of atmospheric refraction and scintillation effects. The engineering and construction of this antenna, like on the 360 foot standing parabola and on the 160 foot helix array, was done by university students. Much of this design and engineering work is combined with course and degree requirements. For example, the design and engineering on the 360 foot standing parabola is being done by Robert T. Nash as part of this Ph. D. dissertation. Previously, he built and measured the performance of the scale model of this antenna at 1.25 centimeters wavelength as part of his Master's thesis.

In addition observations at 11 meter wavelengths have been made during 1956 and 1957 of radiation from the Sun, Jupiter, Venus, and the comet Arend-Roland. The antennas used have included interferometers and a lobe sweeping array of 3 helical antennas.

During the period 1954-57, seven students have received the Master's degree and two the Ph. D. degree in radio astronomy at Ohio State. At present, four students are persuing a Ph. D. program and one a M. S. program in radio astronomy.

University of Michigan

Ann Arbor, Michigan

A radio astronomy project at the University of Michigan began in March 1956 with support from an ONR contract. The broad purpose of the program is the development, construction, and operation of equipment to record the radio frequency spectrum of the Sun and of galactic and extra-galactic radio sources over a wide frequency range, and the interpretation of these records. The initial phase of the program emphasizes the study of the active Sun, principally the bursts and outbursts from active regions in the solar atmosphere using sweep-frequency receiver after the manner of J. P. Wild in Sydney, using, however, somewhat higher frequencies. The second phase of the program will be the construction of equipement at the centimeter wavelengths to study not only the active Sun but galactic and extra-galactic radiation.

The radio observatory site is located near the University of Michigan's Portage Lake Observatory which is within a convenient

distance for graduate students. Roads, power, water, control house, etc., have been developed at the site where a 2-foot radio telescope is installed. The telescope is mounted equatorially and is capable of full sky coverage. For solar burst studies three synchronized sweep-frequency receivers are used with this telescope. The receivers are capable of mechanically scanning from 100 to 600 Mc/s, ten times every second. Receiver outputs are displayed on oscilloscopes and photographed.

Observations of the radio-frequency spectrum is closely coordinated with optical observations carried out at the McMath-Hulbert Observatory where the study of solar flares has been a major field of reserach during the past twenty years.

The second phase and major effort of the program will be concentrated at the high-frequency end of the radio spectrum. In order to study spectra of galactic and extra-galactic radiation and solar bursts at these wavelengths it is necessary to have a moderately large precision paraboloid. We have contracted with a commercial company to design, build and erect a 85-foot diameter solid surface steerable paraboloid useful up to 10 000 Mc. Plans call for completion during the summer of 1958.

University of Michigan

McMath-Hulbert Observatory

Pontiac, Michigan

Geomagnetic Disturbances Associated with Solar Flares with Major Premaximum Bursts at Radio Frequencies 200 *Mc/s*

Study of all cases between January 1, 1949 and April 30, 1956 for which there is positive evidence (on the basis of world-wide, 24-hour data) for major bursts during the *premaximum* phase of a flare at radio frequencies $\leqslant$200 Mc/s has shown that this is a relatively rare phenomenon. Probably fewer than 10 per cent of all flares have this type of emission at meter wavelengths. The investigation has shown that the occurrence or non-occurrence of a « major early burst » as above defined provides assistance in identifying the small number of flares that are the potential causes of non-recurrent, sudden commencement type geomagnetic

storms. Geomagnetic storms were reported by at least one observatory within less than 5 days after 92 per cent of the flares with « major early bursts ». The average time interval between flare and start of storm was 2 ½ days.

Resumé of Visually and Photographically Observed Solar Activity at Times of 200 Mc/s Noise Storms Near the 1954 Solar Minimum.

The daily 200 Mc/s records from Cornell and all 200 Mc/s data in the *Quarterly Bulletin* have been examined and compared with calcium spectroheliograms, sunspot records, and flare reports for the calendar year 1954. The study shows that during 1954, the year of solar minimum, enhanced 200 Mc/s radiation was emitted from all regions in which flares occurred and from all regions with spot areas $\geqslant$ 170 millionths of the solar hemisphere and magnetic fields $\geqslant$ 1300 gauss. Furthermore, enhanced 200 Mc/s radiation occurred only when such regions were on the solar disk. On the other hand, relatively large, bright plages and regions with relatively strong green coronal emissions traversed the solar disk without concomitant increases in 200 Mc/s flux.

Detailed Study of the Development of an Active Solar Region, 1954, August 20-27

Study of the formation and growth of a spot and plage on the otherwise undisturbed solar disk in late August 1954 permitted relatively unambiguous intercomparison of optical features and radio-frequency emission. Enhanced emission at decimeter wavelengths followed closely the development of the calcium plage, and the agreement was better between 2800 Mc/s emission and plage area when the latter was measured in units of the disk rather than in units of the hemisphere.

At meter wavelengths, enhanced radiation was associated more with flare activity than with the general development of the spot and plage. There was no evidence of increased flux or bursts at these wavelengths until flares began to occur in the region, three days after its formation. It should be noted that increased 200 Mc/s radiation of the « noise storm » type was recorded when the region was as much as 65° from the center of the solar disk.

Contributions

(*a*) *The Relation between Observed Solar Features and Solar Radio Emission.*

(*b*) *Relation between Optical Solar Features and Solar Radio Emission.*

These two papers have somewhat similar material in them. The ideas are primarily as follows :

(1) The fully developed, flare-associated event at both decimeter and meter wave lengths appears to exhibit two parts, but either of the two parts may occur separately. The first or « early » part of the double pattern is a sudden burst that starts with the Hα flare and is usually over by the time Hα maximum has been attained. The second or « late » component is usually an enhancement that begins more gradually and reaches its maximum as the Hα flare is fading or is over. At 200 Mc/s the *fully developed* second part appears to be identical with the feature known as a « noise storm ».

(2) Certain observations and measurements indicate that calcium plages are better indicators of the regions emitting enhanced decimeter radiation than are sunspots. It is less necessary to postulate a variation in the « quiet sun » at decimeter wavelengths if calcium plages rather than sunspots are used as indicators of solar « activity ».

(3) The relationship between the well defined pattern of flare emission at single frequencies and the important « dynamic spectra » at radio frequencies is not yet clear. All published examples of spectrum drift for Wild's type II bursts (outbursts) for which detailed flare information exists (only four cases !) refer to the *late* stages of the flares and therefore presumably to the late or second parts of the double flare pattern.

(4) On the assumption that flares at the onset of 200 Mc/s noise storms identify the solar regions from which the enhanced radiation is emitted, it has been shown that in general :

(*a*) for regions within 25° of the central meridian the amplitude of the superposed bursts is *less* than the intensity of the continuum ;

(*b*) for regions more than 50° from the central meridian the amplitude of the superposed bursts is *greater* than the intensity of the continuum.

Summary of Work in Radio Astronomy at the Department of Terrestrial Magnetism, Carnegie Institution of Washington for the years 1953-1957

Mills Cross. — A cross array of the type suggested by Mills was constructed for observations at 13.5 meters wavelength and placed in operation in 1954. Relative intensities of the strong sources were measured and the source Cygnus X was seen in absorption. A careful survey of a strip of sky near the zenith was made.

Jupiter. — Early in 1955 it was discovered that Jupiter is a variable source of radio noise at 13.5 meters. A special array was constructed to observe the planet many hours a day and to determine the polarization of the radiation. The radiation proved to be usually circularly polarized. Spectral characteristics of the radiation were also studied.

Sun. — Near the sunspot minimum in 1954, the brightness distribution of the quiet Sun was measured at 1.45 meters using a variable spacing interferometer. The measurements showed a non-circular distribution, but one shaped in general like the one predicted by Smerd.

Flux. — Attempts have been made to measure the absolute flux received from the strong radio sources. These measurements have all been made in the low frequency range (10 to 50 Mc) and have been made with simple antennas (half wave dipoles) so that antenna gain may be calculated.

21 *cm.* — Meridional surveys have been made at many galatic longitudes. A 50 channel receiver has been built and placed in operation.

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Report of Dr M. Laffineur, Chairman

to the Plenary Opening Session

(Translation)

At the beginning of the XIIth General Assembly of our Union, Commission V is faced with a very full programme: this is due to the rapid increase of work on Radio Astronomy throughout the world. In this connection let us recall briefly the stages of development of our Commission.

Established as one of the research groups of U.R.S.I. in 1946, its character at that time was essentially that of a group concerned with radio and the title of Commission on Radio Astronomy, adopted in 1952, expressed this emphasis on radio technique. The radio engineers who founded this new branch of astronomy have in many cases become expert astronomers : on the other hand, astronomers have been quick to recognise its importance and have assimilated our techniques with immense possibilities.

The meetings of U.R.S.I. and of the I.A.U. have made an effective contribution to this process of the rapid development of Radio Astronomy which at the present time is making a great contribution to the development of modern astronomical knowledge.

This young and lively branch of an ancient science in effect makes possible the study of matter which exists in an extremely dilute state in the atmosphere of stars and also, in enormous masses, in the interstellar space of galaxies. These clouds of matter, even in the most favourable cases, have been extremely difficult to study by optical methods.

With the increase of the number of permanent radio astronomical observatories in the world, which now exceed 50, and with the corresponding growth of staff and the increasing perfection of instruments, new chapters in astronomy have been written

which are of such interest that the subject of the technique which led to their development is taking second place. This evolution is normal, logical and welcome ; it implies a compliment to the pioneers and to their work.

Commission V ought to play the part of a moderator and the programme of our meetings has been drawn up with this intention. After consultations with my eminent colleagues and in particular with Dr. Pawsey, the president of Commission 40 of the I.A.U., I have reached the conclusion that we should emphasize the development of instruments, aerials, receivers and methods of observation. We shall also discuss the effects of the media traversed by the radiation and finally, in spite of all, certain results are to be considered preferably from the point of view of the comparison of different methods. Theories of the mechanism of radio-frequency emission in ionized media will also be discussed.

All these fields of research are in the domain of U.R.S.I., while programmes of observation, results in general and their cosmological implications belong to Commission 40 of the I.A.U. where in the future radio astronomy will probably extend over new specialized commissions.

Those Sub-Commissions which are still active will present their reports at this meeting. The work of Sub-Commission V*d* merits special attention: the methods of standardizing radiometers should be compared and discussed on an international scale : this young Sub-Commission of U.R.S.I. has presented us with an important report ; I hope that contacts will be established ,during the present Assembly, between its members and those of Commission I who, for several years, have been tackling similar problems.

Our working sessions will take place following the timetable which you will find attached to the notice board. The number of sessions on this programme may seem to you to be rather great but any reduction would have resulted in some regrettable omissions. When a field of research grows it becomes specialized, and certain sessions hold more interest for some and less for others. Our colleagues will sometimes be obliged to make a choice and the organizers apologise for this in advance.

Those who wish to participate in discussions, if they intend to make important contributions, should preferably discuss the matter with the president of the particular session.

I hope that our discussions will be fruitful and after having read the fifteen reports of the National Committees I am convinced that I shall have the pleasure at the end of the present assembly of giving you a summary which promises well for the future of our work.

In conclusion I would like to thank on behalf of the Union all those people who have so willingly given their time to the preparations for the meetings of Commission V, among them it is a pleasure to name, our Vice-President Dr. Hagen, Mrs. Martyn, Lovell, Pawsey, Christiansen, Burke, also Colonel Herbays and the Secretaries of Commission V, Messrs. Hanbury Brown and Coutrez.

Minutes of the Sessions

Coordinating Meeting : Monday, August 26th at 2.00 p.m.

Mr. LAFFINEUR in the chair.

Subject : *Programme of the technical sessions and other miscellaneous matters.*

The chairmen of the technical sessions outlined the proposed programme of each session and invited further contributions.

The future of the various Sub-Commissions of Commission V was discussed. Sub-Commission V*b* has already been disbanded ; it was the opinion of the meeting that Sub-Commission V*a* should be discontinued, but that V*c* and V*d* should continue.

The President stated that it was proposed to hold a joint Symposium with the I.A.U. on Radio-astronomy in Paris in 1958. It was proposed to appoint an organizing committee to discuss the topics of this Symposium and to prepare a recommendation for submission to the General Assembly. It was agreed that the members of this Committee would be, the Presidents of Commission V of U.R.S.I. and Commission 40 of I.A.U., Drs. Vitkevitch, Minkowski, Denisse, Lovell, Van de Hulst and Haddock.

First Session : Wednesday, August 28th at 9.30 a.m.

W. N. CHRISTIANSEN in the chair.

Subject : *Receiving techniques.*

The chairman introduced the subject and contributions were made as follows. A. E. COVINGTON : some antenna systems used to study the Sun at 10 cm ; E. J. BLUM : the 169 Mc/s multi-element interferometer at Nançay. A. HEWISH : the principle of aperture synthesis and some aerial systems at Cambridge (U. K.). B. F. BURKE : an interferometer for solar observations on 300 Mc/s at the Carnegie Institution. W. N. CHRISTIANSEN : an aerial system designed to scan the Sun at 21 cm using two 32 element

arrays combined in a Mills Cross. R. N. Bracewell : two theorems dealing with the minimum number of points at which interferometer observations need to be made and the restoration of data. T. Hatanaka : an interferometer for observing fast bursts of solar radio emission at 200 Mc/s. J. Aarons : a wide-band radiometer at 4600 Mc/s using travelling-wave tubes. R. S. Lawrence and H. Penfield : a phase-tracking interferometer for the study of scintillations and position drifts at 53, 108 and 470 Mc/s. M. H. Cohen : a polarimeter for studying solar bursts at 201.5 Mc/s. P. D. Strum : the factors governing the performance of a radiometer : R. V. Eshleman : an antenna system on 13 m comprising 96 Yagis for the detection of faint meteors. C. Seeger : the report of Sub-Commission V*d* on the measurement of flux-density. H. W. Wells : measurements of the flux-density from Cassiopeia A in the frequency range 18.5 Mc/s to 207 Mc/s. D. A. MacRae : an interferometer system for 300 Mc/s.

Second Session : Wednesday, August 28th at 2.00 p.m.

A. C. B. Lovell in the chair.

Subjects : *Large aerials* (*joint meeting with Commission VI*).

The chairman introduced the subject and the following papers were read. F. Becker : the 25 m paraboloid at Bonn. C. A. Muller : the 25 m paraboloid at Dwingelo. D. V. Korolkov : a large aerial system for use at 3 cm at Pulkovo. J. D. Kraus : the 96 helix array at Ohio State University for 200-300 Mc/s, and a large parabolic reflector under construction. R. N. Bracewell : a cross type of aerial for scanning the Sun at 9 cm under construction at Stanford University. M. Laffineur : an interferometer comprising two 60 × 32 m cylindrical parabolae at St. Michel. A. C. B. Lovell : a 250 ft. steerable paraboloid at Jodrell Bank. R. M. Emberson : the design of the proposed 140 ft. paraboloid at Green Bank. J. L. Pawsey : a design study of a 230 ft. steerable paraboloid. J. G. Bolton : two 90 ft. paraboloids designed to act as an interferometer under construction at the California Institute of Technology. F. T. Haddock : an 85 ft. paraboloid at the University of Michigan. E. F. McGlain: an 85 ft. paraboloid at the Naval Research Laboratory, Washington.

G. W. SWENSON : a project for a 400 × 600 ft. parabolic cylinder for use at 50 cm at the University of Illinois. V. VITKEVITCH : plans for building large radio-telescopes in the U.S.S.R. J. D. KRAUS : general considerations relating to the number of sources detectable with a radio-telescope. J. L. PAWSEY : the effective resolution limit of a radio-telescope. R. N. BRACEWELL : the effects of errors in the construction of a radio-telescope. L. C. VAN ATTA : possible alternative designs for very large aerial systems.

The meeting was adjourned at 5.30 p.m. and was continued on Thursday, August 29th at 11 a.m. under the chairmanship of R. C. SPENCER.

The chairman gave a brief introduction and the following contributions were made : S. SILVER : a number of questions in the design of large aerial systems ; J. L. PAWSEY : some general questions in the design of large aerials. J. W. FINDLAY : considerations in the design of the 140 ft. paraboloid for Greenbank. E. WOLF : recent work on the theory of partially coherent fields, and some remarks on the reciprocity relations between the bandwidth and duration of a signal. R. N. BRACEWELL : remarks on the use of the correlation function. F. J. ZUCKER : some theoretical results on the optimum f/d ratio, the difference between discrete and continuous arrays, and coherence over the aerial aperture. Short contributions on the effects of errors in aerials dimensions were also made by J. SIMON and F. T. HADDOCK.

Third Session : Thursday, August 29th at 2.00 p.m.

D. F. MARTYN in the chair.

Subject : *The Sun.*

The subject was introduced by the chairman. The following papers were than read. A. HEWISH : eclipses of the Crab Nebula by the Sun ; V. VITKEVITCH : eclipses of the Crab Nebula by the Sun, inhomogeneities in the outer corona, limb brightening. R. J. COATES : eclipse observations in 1954 at 8.6 mm wavelength, observations of the Sun at 3.4 mm. V. VITKEVITCH : two dimensional brightness distribution of the Sun at 3 cm. W. N. CHRISTIANSEN : the slowly varying component of the solar emission at 21 cm, the polar diagram of the active regions, their relation to

plage size and their height. T. HATANAKA : observations of the intensity and polarization of bursts from the Sun at 3 cm. D. V. KOROLKOV : the polarized emission from sunspots observed at 3 cm. F. H. MITCHELL : variations in the apparent temperature of the Sun at millimetre wavelengths. J. L. STEINBERG : observations of solar bursts at 3 cm. A. E. COVINGTON : the classification of bursts observed at 10 cm. C. A. MULLER : rapid bursts observed at 400 Mc/s. J. L. Pawsey : the dynamic spectra of different types of bursts. J. F. DENISSE : some observations of cirularly polarized radiation at 169 Mc/s which follows certain outbursts. A. MAXWELL : the dynamic spectra of bursts. M. H. COHEN : observations at 200 Mc/s with a polarimeter. R. FLEISCHER : the detection of solar flares by absorption of cosmic noise at 18 Mc/s. J. F. DENISSE : observation of sunspot radiation at 169 Mc/s, the height and diameter of the sources of emission, an eclipse of the Crab Nebula by the Sun. Mrs. DODSON PRINCE : the relation between solar events and geomagnetic storms. T. GOLD : the shape of the magnetic field between the Sun and the Earth and the streaming of material in this region. T. TAKAKURA : the mechanism of emission of polarized bursts : R. J. COATES : 10 cm, 4.3 mm and Hα observations of flares. J. F. DENISSE : the relation between the ionization of region E and 10 cm solar radio emission, coronal line emission and sunspot area.

Fourth Session : Friday, August 30th at 9.30 a.m.

J. L. PAWSEY in the chair.

Subject : *Radio Sources.*

The chairman gave a brief introduction and the following papers were read : R. HANBURY BROWN : the distribution of intensity across Cygnus A and Cassiopeia A at 125 Mc/s, the angular diameters of Cassiopeia A and Taurus A at 10.7 cm and of several small sources at 158 Mc/s. C. SEEGER : isophotes of the Andromeda Nebula (N.G.C. 224) at 400 Mc/s. A. HEWISH : the spectral index of different types of sources. H. C. Ko : a survey of sources, the spectra of sources. J. F. DENISSE : some observations of sources at 900 Mc/s and at 169 Mc/s. M. SCHMIDT : a survey of sources at 22 cm. N. G. ROMAN : a survey at 440 Mc/s, the flux-density of a number of sources. A. HEWISH : a survey of

sources at 160 Mc/s, with comments on the number and intensity distribution. J. L. PAWSEY : a survey of sources at 85 Mc/s with comments on a comparison of the results with those obtained at Cambridge (U.K.). C. SEEGER : observation of the Coma cluster at 400 Mc/s. F. BECKER : the statistics of sources in a relativistic cosmology. C. H. MAYER : observation of polarized radiation from the Crab Nebula at 3.15 cm. V. VITKEVITCH : occultation of the Crab Nebula by the Moon at 3.7 m. J. F. DENISSE : occultation of the Crab Nebula by the Moon at 177 cm and 33 cm. J. TUOMINEN : occultation of the Crab Nebula by the Moon at 3.7 m. C. SEEGER : occultation of the Crab Nebula by the Moon at 75 cm.

Fifth Session : Friday, August 30th at 2.00 p.m.

A. HEWISH in the chair.

Subject : *Radio Propagation.*

The chairman introduced the subject by describing the various effects which can be produced on extra-terrestrial waves by the Earth's atmosphere. A. C. B. LOVELL : the correlation between scintillations, spread F, and magnetic variations. V. VITKEVITCH : research on the irregular structure of the ionosphere by radio astronomical methods. C. G. LITTLE : observations of scintillations at 223 Mc/s and 456 Mc/s in Alaska. J. TUOMINEN : observations of scintillations in Helsinki at 45 Mc/s. A. HEWISH : an investigation of the height of the regions causing scintillation. J. AARONS : studies of refraction and scintillation at low angles of elevation at 8.3 cm, 3 cm, 1.4 m. G. R. MARNER : observations of refraction and absorption at 8.7 mm and 1.9 cm. J. L. STEINBERG : scintillation of the solar emissions at 3.2 cm at low angles of elevation. R. J. COATES : atmospheric attenuation at 4.3 mm. R. L. LEADABRAND : irregularities in regions E and F observed with oblique-looking radars. H. G. BOOKER : a review of the various methods by which the height at which scintillations take place can be determined. A. C. B. LOVELL : remarks on the origin of scintillations. G. A. HARROWER : the connection between. scintillations and the accretion of interstellar material by the Sun.

Sixth Session : Monday, September 2nd at 2.00 p.m.

R. HANBURY BROWN in the chair.

Subject : *The Galaxy.*

The chairman gave a brief outline of the subject. The following papers were then read : H. C. Ko : the results of a survey at 250 Mc/s. J. L. PAWSEY : a comparison of surveys of the galactic plane at 19 Mc/s and 85 Mc/s. M. SCHMIDT : a survey on 1390 Mc/s. A. HEWISH : a survey on 38 Mc/s using aperture synthesis. M. SCHMIDT : spiral structure in the centre of the Galaxy observed at 21 cm. J. L. PAWSEY : a survey of the spiral structure of the Galaxy made at 21 cm in the southern hemisphere. C. A. MULLER : measurements of absorption lines at 21 cm in the radiation from Cassiopeia A and Taurus A. T. K. MENON : 21 cm observations of stellar associations and galactic clusters.

D. S. HEESCHEN : 21 cm observations of clusters of galaxies and individual galaxies. M. SCHMIDT : 21 cm observations of the Andromeda Nebula (N.G.C. 224). J. G. BOLTON : a comparison of the sources observed by Mills with the Palomar sky survey, and some remarks on the nature of extra-galactic radio sources. A. H BARRETT : a search for an interstellar OH line.

Seventh Session : Tuesday, September 3rd at 0.930 a.m.

B. F. BURKE in the chair.

Subject : *The planetary system.*

The chairman introduced the subject and the following papers were presented : J. H. TREXLER : the characteristics of radar echoes from the Moon, and the Moon as a possible communication link. S. B. YAPLEE : radar observations of the Moon at 10 cm. A. C. B. LOVELL : libration fading and the polarization rotation of radar echoes from the Moon at 120 Mc/s. R. B. DYCE : radar observations of the Moon. J. H. CHAPMAN : radar observations of the Moon at 488 Mc/s. C. H. MAYER : thermal radiation from Venus, Mars and Jupiter at 3.15 cm and from Venus at 9.4 cm. H. I. EWEN and F. DRAKE : a wide band radiometer at 8000 Mc/s, and observations of the Moon, planets, and some radio sources including planetary nebulae. R. CALLET : the non-thermal radiation from Jupiter . K. L. FRANKLIN : the non-thermal

radiation from Jupiter. Short contributions on observations of Comet 1956*b*) Arend-Roland were then presented by R. COUTREZ, F. BECKER, J. D. KRAUS, A. C. B. LOVELL, G. SWARUP, J. L. PAWSEY, J. AARONS, E. J. BLUM and C. SEEGER.

Administrative Session : Wednesday, September 4th at 9.30 a.m.

M. LAFFINEUR in the chair.

1. The President summarized the work done by Commission V during the General Assembly.

2. Sub-Commission V*a* on « Continuous Measurements of Solar Radio Emission ». It was decided at the previous meeting that this Sub-Commission should be discontinued. The President expressed the thanks of Commission V to A. H. De VOOGT for his pioneering work with this Sub-Commission.

It was proposed to appoint a member of Commission V to the Committee on Ursigrams.

3. Sub-Commission V*c* on « Basic Solar Index ». It was decided to continue this Sub-Commission with new membership (see Resolutions).

4. Sub-Commission V*d* on « Standards ». This Sub-Commission has reported on the measurement of flux densities. The report was accepted and it was decided that the Sub-Commission should continue with new membership (see Resolutions).

5. The subject of frequency allocation for radio-astronomy was discussed. It was agreed that members should approach the appropriate authorities in their own countries to seek clearance of frequencies for radio-astronomy. It was also agreed that some members of U.R.S.I. would approach their appropriate national representatives with the object of submitting a recommendation on frequency allocation to the International Telecommunication Union at their next conference in 1959.

It was decided that the subject of frequency allocation should be removed from Sub-Commission V*d* and that a new Sub-Commission V*e* on « Frequency Allocation » should be set up (for details of the proposed membership see Resolutions).

J. W. FINDLAY outlined the steps being taken at the new radio observatory at Greenbank to reduce the effects of interference.

6. A. C. B. Lovell drew attention to the difficulty in separating the fields of interest of Commissions III and V. It was agreed to set up a working party, consisting of the Presidents of Commissions III and V to clarify the relations between the subjects discussed.

7. The meeting endorsed the recommendation by Sub-Commission V*d* that U.R.S.I. should designate certain standard radio sources. It was decided that this recommendation should be forwarded to the I.A.U. for consideration by Commission 40 (for details of the recommendation see Resolutions).

8. J. L. Pawsey reported the recommendations of the organizing committee set up to consider the proposed Symposium on radio-astronomy to be held in France in 1958. The recommendations of the committee were accepted by the meeting (for details see Resolutions).

9. The meeting expressed its thanks to the President and Secretaries of Commission V.

Joint Sessions

Joint sessions with other Commissions were held as follows :

Commission VI on Large aerials, on August 28th, 29th (reported above).

Commissions III and IV on Whistlers, on August 29th.

Commission VII on Masers, on September 3rd.

Summary of the proceedings of the Sessions

submitted at the Plenary Closing Session

by Dr. M. LAFFINEUR, *Chairman*

President, Ladies and Gentlemen,

Commission V has just finished its work. In the course of our administrative session yesterday certain resolutions and recommendations were drawn up. However, before embarking on a summary of them, I should like to give you a brief description of the growth of Radio-Astronomy and of the new developments which were described, often by the authors themselves, in the course of our nine working sessions.

Aerials have been the subject of original and, judging from the results, important work, for example ;

A new type of « synthetic » aerial comprises a fixed element and a mobile element which can be moved over a large area of ground. Successive measurements, made with the mobile element in different positions, yield information on the distribution of radio emission over the sky equivalent to that which would be given by a single reflector extending over the whole area.

A large interferometer, consisting of 64 mirrors each with a diameter of 6 metres, has been designed to give observations of the Sun with a resolving power of 3 minutes of arc in both longitude and latitude.

Several new types of large aerial have been designed with reflecting surfaces in the form of sections of paraboloids or cylindrical paraboloids. We must also note some very large aerials consisting of helical elements.

These huge systems for collecting radio waves are sometimes to be found coupled together as interferometers.

The largest steerable paraboloid in the world, which has a diameter of 76 metres, has just been tested successfully on a wavelength of 21 centimetres.

There is a tendency to increase the precision of the surface of large reflectors ; in many cases, even with diameters greater than ten metres, it is becoming possible to use wavelengths of the order of a centimetre. This tendency is readily explained by the fact that receivers have recently made new advances towards improved resolving power in temperature. At the present time there are receivers which, in the 3 cm wave-band, enable changes of input temperature of the order of one hundredth of a degree centrigrade to be observed.

Amplifiers using stimulated emission (MASERS) have not yet, to my knowledge, been used in radio-astronomy ; but the masterly lectures which we have heard give us hope, in the near future, of greatly improved resolving power in temperature.

All these advances in technique have brought with them new results : the lower corona of the Sun can now be observed on 21 cm, on the disc and the limb at once, thereby realizing a dream of solar astronomers. The dynamic spectrography of bursts of solar emission, carried on with increased facilities and interpreted by well established theories, has now disclosed new types of solar radio-frequency phenomena in which one can follow the ejection, and subsequent falling back into the photosphere, of gas expelled by chromospheric eruptions.

In the domain of the general observations of radio emission from the sky, we may note the important contributions presented in the form of maps showing isophotes taken on several different wavelengths and using aerials with a resolving power of one degree or sometimes even less.

Thanks to the combined results of observatories in the northern and southern hemispheres, made on the 21 cm wavelength line from cold interstellar hydrogen, we have seen a preliminary outline of the general structure of our spiral galaxy. We live in a galaxy rather similar to that in Canes Venatici.

The distribution of the Radio Sources has been discussed ; researches in this field are long and laborious, and their interpretation is still uncertain. They must be persued with patience, compared objectively, and made more exact. Then they will

be able to bring important developments in our knowledge of cosmology.

The galactic centre has been studied recently, it is observed either in emission, or in absorption, according to the wavelength used. The contribution of radio-astronomy to this field of research is fundamental, it will greatly improve on the optical observations which are hampered by the dark clouds of interstellar material which lie between us and the centre of our local system.

The angular resolving power of the new instruments has made it possible to identify and study in our own galaxy bodies of gas which are expanding around the stellar associations observed by optical astronomers.

The structure of the spiral nebula in Andromeda (Messier 31) has been observed successfully. The polarization of the emissions from the Crab Nebula provides a measure of support for the theory that the radiation from relativistic electrons in interstellar magnetic fields represents the origin of the non-thermal emission from radio sources.

The thermal emission from the planets Venus, Mars and Jupiter has been definitely observed, thanks to new and complicated receivers which have great resolving power both in angle and temperature.

The radar-echo technique, applied to the Moon, has yielded precise distances to our satellite. We listened with some emotion to a recording on magnetic tape of a beautiful experiment, made in this country, in which a modulated wave was transmitted towards the Moon and the echo was heard, after a delay of 2.4 seconds, reproducing faithfully the brief words spoken into a microphone. This experiment, which employed no more than 100 watts of transmitted power, shows the possibility of bringing into practical use this new method of telecommunication.

There is a long-term fading of lunar echoes which is still unexplained.

Radio observations of the Comet Arend-Roland have given somewhat discordant results, submitted to the sagacity of physicists.

Resolutions

1. Sub-Commission V*a* on « continuous measurements of solar radio emission » should be discontinued.

2. A member of Commission V should be appointed to the Permanent Committee on Ursigrams.

3. Sub-Commission V*c* on « the basic solar index » should be continued with the following membership :

Chairman : S. CHAPMAN.
Members : J. BARTELS,
A. E. COVINGTON,
M. NICOLET,
M. WALDMEIER,
S. F. SMERD,
J. F. DENISSE,
C. M. MINNIS,
H. DODSON-PRINCE,
R. N. BRACEWELL,
A. MAXWELL.

4. Sub-Commission V*d* on « Standards » should be continued with the following membership :

Chairman : C. SEEGER.
Members : A. E. COVINGTON,
F. T. HADDOCK,
M. LAFFINEUR,
D. A. MACRAE,
C. H. MAYER,
F. G. SMITH.
J. L. STEINBERG,
T. HATANAKA,
R. HANBURY BROWN.

5. The Commission endorses the following recommendation put forward by Sub-Commission V*d* :

« There is now general agreement on the desirability of esta-

blishing certain of the stronger discrets sources as members of a standard sequence of flux density. To achieve this objective, it is desirable that U.R.S.I. Commission V and I.A.U. Commission 40:

(1) designate the following sources as members of a standard sequence of flux density,

23N5A (Cas A)	12N1A (Vir A)
19N4A (Cyg A)	16N0A (Her A)
05N2A (Tau A)	09S1A (Hyd A)

(2) call the attention of all radio astronomy observation to the urgent need for more accurate values for the absolute flux densities of the above sources,

(3) recommend that, in observational studies of discrete sources, greater attention be paid to obtainnig accurate, well defined intensity ratios between the objects under observation and the members of the above standard sequence,

(4) recommend that persons making high resolution « pencil-beam » surveys, pay particular attention to the regions surrounding the above sources and publish their findings in the form of detailed maps, perhaps 30 × 30 degrees and centered on the individual sources. »

Commission V proposes that this recommendation should be forwarded to the I.A.U. for consideration by Commission 40.

6. Commission V expresses its thanks to the I.A.U. and C.C.I.R. for considering resolutions 4 and 5 adopted by Commission V at the XIth General Assembly in 1954. Once again it insists on the absolute necessity that those observatories engaged in radio-astronomy which are troubled by interference should receive the backing of the authorities in their own and neighbouring countries.

7. A new Sub-Commission V*e* on « Frequency Allocation » should be established. This Sub-Commission is charged with preparing recommendations to be submitted through the appropriate authorities to the International Telecommunication Union at

their meeting in 1959. The membership of this Sub-Commission is to be :

Chairman : F. T. Haddock (U. S. A.).

Members : E. J. Blum (France),
A. Hewish (U. K.),
V. Vitkevitch (U. S. S. R.),
W. N. Christiansen (Australia),
A. H. de Voogt (Netherlands),
T. Hatanaka (Japan),
L. Erikson (Norway),
F. Becker (Germany),
A. E. Covington (Canada),
G. Righini (Italy),
J. Tuominen (Finlend),
O. E. H. Rydbeck (Sweden),
R. Coutrez (Belgium),
A. P. Mitra (India).

8. A working party, consisting of the Presidents of Commissions III and V, should examine the division of subjects between these two Commissions.

9. Commission V recommends that U.R.S.I. should assent to the request by I.A.U. to sponsor a joint Symposium on Radio Astronomy in France just prior to the General Assembly of I.A.U. in 1958.

It recommends that the subjects matter should be restricted to those aspects of radio astronomy which are particularly of astronomical interest ; it should include solar, galactic and extra-galactic radio emission together with a short session on radio studies of other bodies of the solar system. The number of scheduled speakers should be restricted so as to leave adequate time for discussion.

It also recommends that the proceedings should be published in book form.

The Commission suggests that the following persons should serve on a joint U.R.S.I.-I.A.U. organizing committee :

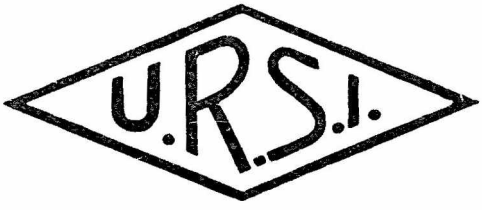
Chairman : J. L. Pawsey (President of Commission 40 I.A.U.).

Secretary : F. T. Haddock.

Members : The Chairman of U.R.S.I. Commission V,
J. F. Denisse,
V. Vitkevitch,
R. Minkowski,
A. C. B. Lovell,
H. C. van de Hulst,
R. N. Bracewell.

J. L. Pawsey, representing the I.A.U. at this General Assembly has informed Commission V that the considers hese proposals entirely acceptable to the I.A.U.

INTERNATIONAL SCIENTIFIC RADIO UNION



Proceedings of the XIIth General Assembly

held in Boulder, Colorado, U. S. A.
from August 22nd to September 5th, 1957

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On Radio Waves and Circuits

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COMMISSION VI

On Radio Waves and Circuits

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Yugoslavia : Ing. Mirjan GRUDEN, Professeur à la Faculté d'Electrotechnique, Aškerčeva cesta 11, Ljubljana.

Sub-Commissions

VI1. — On Information Theory.

VI2. — On Circuit Theory.

VI3. — On Antennas and Wave Guides.

List of Reports and Papers submitted to the Commission

The asterisk indicates reports published in this part.

E = Original text in English.

F = Original text in French.

N°	Titles and Authors
1	C.C.I.R. findings of interest to U.R.S.I., *U.R.S.I. Inform. Bull.*, **100**, 48-81 (E).
5	Contribution to the study of optical noise; Comparison with noise in radioelectricity, A. BLANC-LAPIERRE, Professor at the Faculty of Sciences, Algiers (F).
6	Considerations on the notion of instantaneous frequency of a signal (F).
7	Study on the notion of instantaneous power spectrum. A. BLANC-LAPIERRE and B. PICINBONO, Laboratory of Theoretical Physics, Faculty of Sciences, Algiers (F).
8	Cascaded binary channels, J. LOEB (F).
9	On the Babinet's theorem in the magnetic theory, P. PONCELET (F) ((*C. R. Académie des Sciences*, t. 243, n° 22, Nov. 1956, 1743-1745).
10	Topological methods applied to electronics, L. SIDERIADÈS (F).
11	Determination of the type of emission producing minimum interference, Report submitted to the 1956 Plenary Assembly of C.C.I.R. (E).
12	On the determination of the inverse random function's spectrum and its applications, R. FORTET, Laboratoire Central des Télécommunications, Paris.
13	Instantaneous spectrum and signal analysis. Applications to transmission problems in communications, P. DEMAN (F).
46	On the capacity of a noisy continuous channel, S. MUROGA (E).

N°	Titles and Authors
47	On the capacity of a discrete channel, Part II.Mathematical expression of the capacity of a noisy channel which is expressible by corresponding two multistage diagrams, S. MUROGA (E).
48	Double sampling theorems in continuous signals, N. HONDA, Faculty of Engineering, Tohoku University, Sendai, Japan (E).
49	Transformation of probability distributions and its application to compendor system, H. MINO, Faculty of Engineering, Osaka University, Osaka, Japan (E).
50	The parametron, an amplifying and logical element using varying-parameter resonators, H. TOKAHASHI, E. GOTO, Department of Physics, University of Tokyo (E).
51	General solutions of the logical algebraic equation with many unknowns, M. GOTO, Electrotechnical Laboratory, Japanese Government (E).
52	Theory of negative impendance converter, H. HIRAYAMA, Faculty of Engineering, Waseda University, Tokyo (E).
53	The expansion of electromagnetic fields in cavities, K. KUROKAWA, University of Tokyo (E).
55	On the transition from a ground return circuit to a surface waveguide, H. KIKUCHI, Electrotechnical Laboratory, Ministry of International Trade and Industry, Japan (E).
56	Pseudo-electromagnetic retarding medium using loop coils, K. MORITA, Tokyo Institute of Technology (E).
57	A M-derived waveguide filter, H. YANAI, J. HAMASAKI, Faculty of Engineering, University of Tokyo (E).
58	A distributed coupled surface wave bandpass filter, Y. MORIWAKI, T. KAWAMURA, Institute of Industrial Science, University of Tokyo (E).
59	A broadband coaxial-to-waveguide junction, S. TANAKA, Matsuda Research Laboratory, Tokyo Shibaura Electric Company, Kawasaki (E).
60	Current distribution on a rectangular plate and its effective area, K. MORITA, T. SEKIGUCHI, Tokyo Institute of Technology (E).
61	A new broadband antenna, S. OKAMURA, M. SUMITA, University of Electrocommunications, Tokyo (E).
62	A wide band microwave antenna using circularly polarized waves, S. KAWAZU, Electrical Communications Laboratory, Nippon Telephone and Telegraph Corp., Japan (E).
63	A corrugated plane reflector, Y. MORIWAKI, T. KAWAMURA, Institute of Industrial Science, University of Tokyo (E).

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68	Electromagnetic properties of a rotating plasma, E. CHVOJKOVA (E).
73	Second-harmonic signal generator with semi-conductor diodes, J. KARPINSKY (E).
74	Contribution to the theory of the exponential step-lines, B. G. KAZANSKY, Radio and Electronics Institute, Czechoslovak Academy of Sciences (E).
75	Notes on transmission line equations in terms of normalized impedance and reflection coefficient, B. G. KAZANSKY (E).
76	On the notion of infinitely thin and infinitely conducting screens, P. POINCELOT (*C. R. Académie des Sciences*, t. 243, n° 21, Nov. 1956, 1616-1618) (F).
80	A new method for measuring phase and amplitude distribution of antenna currents, as applied to the reflection-free antenna, E. CASSEL, The Royal Institute of Technology, Division of Theoretical Electrical Engineering, Stockholm (E).
82	The reflection of electromagnetic waves in rough surfaces, Ing. P. BECKMANN (E).
96	Correlation theory of electric fluctuations and thermal radiation, S. M. RYTOV (E).
97	Phase-fluctuations in self-oscillators. Theory and measuring methods, G. GORELIK, L. IOLKINE (F).
98	Propagation of pulses in a strongly non-linear system with delaged feedback, Y. NEIMARK, Y. MAKLAKOV, L. IOLKINE (F).
99	Frequency conversion by a reflex klystron, E. N. BAZAROV, M. E. ZHABOTINSKY, Institute of Radio Engineering and Electronics, U.S.S.R. Academy of Sciences (E).
100	Group velocity of attenuated waves, L. A. WAINSTEIN (E).
101	On the theory of the Maser and fluctuations of its oscillations, V. S. TROITZKY, Radio-Physical Institute of the Gorky State University (E).
102	Surface Electromagnetic waves, M. A. MILLER, V. I. TALANOV (E).
106	Remarks on statistical methods in Communication theory, J. SEIDLER (E).
107	Systematization of the influence of non linear factors on the L-C generator frequency, J. GROSZKOWSKI (F).
108	Uniform realization of operators by means of linear elements, R. KULIKOWSKI (E).
109	Estimation methods in the theory of non-linear and parametric filters, R. KULIKOWSKI (E).

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110	Pulse propagation in wave guides, R. GAJEWSKI (E).
113	Guided waves, Prof. H. BARLOW, University College, London, U. K. (E).
118	Analysis of d. c. networks including ideal rectifiers, G. BIORCI Istituto Elettrotecnico Nazionale « Galileo Ferraris », Torino, Italy (E).
119	Negative resistance two-ports considered as reactive elements governed by a voltage or a current, L. PIGLIONE (F).
121	Operational calculus, Fourier Transform or Laplace Transform, W. PROCTOR WILSON, C. G. MAYO, J. W. HEAD, Research Department, BBC Engineering Division (E).
129*	British National Progress Report to Commission VI, W. PROCTOR WILSON, J. W. HEAD, G. D. MONTEATH, H. M. BARLOW (E).
130	Surface wave research at University College, London, Dr. John BROWN (E).
131	The application of diffraction theory to aerial measurement problems, same author (E).
132	Survey paper on guided waves, Prof. H. M. BARLOW, University College, London (E).
133	An approximate realization of « Quadrature », G. G. GOURIET, G. F. NEWELL, British Broadcasting Corporation (E).
134	The negative centropy recorded information, D. A. BELL, University of Birmingham (E).
135	Propagation characteristics of low-loss tubular metal waveguides, Prof. H. M. BARLOW, University College, London (E).
136	A note on the definition of group-delay, G. G. GOURIET, A.M.I.E.E., Research Department, BBC (E).
137	A method for calculating the horizontal radiation patterns of dipole arrays around support masts of intermediate size, P. KNIGHT, British Broadcasting Corporation (E).
143*	Report of the Swiss National Committee to Commission VI, Prof. BALDINGER (E) (F).
150*	Survey of circuit theory Report of Sub-Commission VI2 on Circuit Theory, Prof. Ir. B. D. H. TELLEGEN, Chairman (E)
154	Draft of an U.R.S.I. monography. Information theory of a complete communication system, J. LOEB (E).
163*	Report of the Italian National Committee to Commission VI (E).
188*	Report of the Canadian National Committee to Commission VI (E).

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195*	Report of the German National Committee to Commission VI (E).
202*	Report of the Japanese National Committee to Commission VI, K. MORITA (E).
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212*	Report of the French National Committee to Commission VI (F).
218*	Report of the Swedish National Committee to Commission VI, E. HALLEN (E).
221	Junction converting rectangular TE_{01} waves into circular TE_{01} waves, M. P. MARIÉ (F).
226	Lens focalizing circularly polarized waves into a given mode, M. P. MARIÉ (F).
233*	Report of the Netherlands National Committee to Commission VI (E).
234	On codes for error-correction and for automatic repetition systems, F. L. H. M. STUMPERS, Philips Research Laboratories (E).
235	Electromagnetic wave reflexion and space charge wave propagation in electron streams, O. E. H. RYDBECK, Research Laboratory of Electronics, Chalmers University of Technology, Gothenburg (E).
261*	U.S.A. National Committee Report to Sub-Commission VI-3 (E).
262*	Report of the Sub-Commission VI-3 (E).
271	Method of electronic phototelegraphy with high efficiency of information transmission, V. A. ILYIN (E).
272	Electrodynamics of material bodies, L. J. CHUI (E).
273	On the capacity of channels with random parameter fluctuations, V. I. SIFOROV (E).
276	Far field scattering from bodies of revolution, K. M. SIEGEL (E).
277	An anti-multipaths communication system (Rocke), R. PRICE, P. E. GREEN Jr. (E).
278	Notes on the difference between one-dimensional time filters (Networks), two-dimensional space filters (Optics), and three (or more) dimensional space-time filters (Antennas), F. J. ZUCKER, Air Force, Cambridge Research Center, U.S.A. (E).
300*	Report of the U.S.A. National Committee to Commission VI (E).

N°	Titles and Authors
301	A multiplication theorem for positive real functions, F. REZA (E).
307	Scattering from a circular loop, V. H. WESTON, University of Toronto (E).
308	Vector wave functions in toroidal coordinates, V. H. WESTON (E).
311	Far field scattering from bodies of revolution, K. M. SIEGEL (E).

Reports of Sub-Commissions

N° 150. — Survey of Circuit Theory
Report of Sub-Commission VI.2

The object of this report is to serve as a background for a discussion during the General Assembly of the general aspects of circuit theory. It will deal successively, and in a broad sense, with subject, tasks, results and open questions of circuit theory. At the session the report will be considered read.

1. — Subject

1.1. — The object of radio and allied apparatus is to convey and transform « information ». This is achieved by means of energy carrying the information. From a physical point of view the apparatus is therefore a system in which energy exchange and conversion takes place. Circuit theory pays attention only to this energy play. Thus, if the word «signal» is used in circuit theory, it should not be considered as representing information, but as a source of energy and the currents and voltages resulting from it. The information aspect of the apparatus is covered by Sub-Commission 1, on Communication and Information Theory.

1.2. — The systems of circuit theory are generally provided with terminals allowing energy exchange with the exterior. The systems are considered by circuit theory to be characterized by the relations, generally differential equations, that they determine between the instantaneous values of the currents and voltages at the terminals. Circuit Theory considers only systems characterized by relations that contain only the time as independent variable, but do not contain space coordinates. Systems whose properties are characterized by relations containing both time and space coordinates, are covered by Sub-Commission 3, on Antennas and Wave-guides.

1.3. — The systems, generally, are networks of components. The components are themselves to be considered as systems characterized by relations between the currents and voltages at the terminals. Circuit theory does not pay attention to the physical means by which the components are realized, i. e., to the construction of the components and to the properties of the materials used for them. For circuit theory the components are « black boxes ». A component may be, for example, a resistance (characterized by the relation $v = Ri$), but may also be a black box with more complicated properties. As a consequence, in circuit theory the temperature concept does not enter. The problems in connection with the construction of the components and the materials used are mostly covered by Commission VII, on Radio-electronics.

To summarize :

Circuit theory is the theory of networks composed of black boxes, characterized by relations between the currents and voltages at the terminals, which relations contain only time as independent variable, and contain neither space nor temperature coordinates.

2. — Task

2.1. *General properties.* — The first task of circuit theory, just as of any physical theory, is to find general properties of its subject. Some properties only refer to the geometrical configuration of the network and not to the properties of the network components. These are *topological* properties, of which the Kirchhoff rules are simple examples. Other properties also depend on the properties of the components, of which the reciprocity relations of networks composed of resistance, inductances, and capacitances are examples.

2.2. *Analysis.* — If the network is given, i. e., the network configuration and the relations characterizing the components, methods should be developed to calculate the currents and voltages in the network. In particular, if a network provided with terminals is given, the methods should enable one to calculate the relations between the currents and voltages at the terminals.

2.3. *Synthesis.* — If a network is provided with n terminals, the state of the terminals is characterized by n-1 independent

currents and n-1 independent voltages. The network determines n-1 independent relations between the currents and voltages. The terminals can be combined to m groups such that the sum of the currents flowing to the terminals of a group is always equal to zero. The number of independent currents thereby reduces to n-m. If we are not interested in the voltages between terminals belonging to different groups, the number of independent voltages in which we are interested, also reduces to n-m. The smallest number of groups is 1, the largest number $\frac{1}{2}(n\text{-}1)$ or $\frac{1}{2}n$. In the last case the network has $\frac{1}{2}n$ terminal pairs or ports.

The problem of synthesis can now be stated as follows [1] :

1. given a class of networks, i. e., a number of terminals, a grouping of the terminals, a class of configurations (e. g., ladders, or any configuration), a class of components (e. g., R's, L's, C's and ideal transformers), and possibly restrictions about the distribution of the components in the configuration (e. g., a two-port consisting of an L, C two-port with a resistance in parallel with one of the ports) ;

2. given a class of functions of the network class (e. g., the transfer impedance of a two-port, or the impedance matrix of an n-port) ;

3. find necessary and sufficient conditions for the function class to be realizable by the network class ;

4. find a canonical network class, i. e., subclass of the network class that is sufficient for the realization of the entire function class ;

5. find a technique for calculating the component values of the canonical network class, given any specified function in the function class ;

6. find all equivalent networks, i. e., the networks in the network class that have the same function in the function class.

2.4. *Requirements.* — Most technical applications of network lead to requirements that are not of the kind mentioned in subsec. 2.3. Special investigations, different to each of the many applications, are necessary to reduce them to this kind. A certain

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[1] The points 1-5 correspond to those given by DARLINGTON (1).

class of applications leads to the problem of constructing a transfer function that is realizable in a given network class and of which the amplitude-ratio-versus-frequency and the phase-shift-versus-frequency function in given frequency bands approximate given frequency functions (*synthesis in the frequency domain*). Another class of applications leads to the problem of constructing a transfer function that is realizable in a given network class and for which a given time function at the input causes a time function at the output that approximates a given time function (*synthesis in the time domain*).

2.5. *Arsenal.* — In general we shall be the better able to satisfy requirements as mentioned in subsec. 2.4, the more complicated we are allowed to make the network. We therefore need a classification of the networks of a network class according to the complexity (1). Because of the existence of equivalent networks, it is generally a simpler problem to classify the corresponding functions in the function class. When a classification is chosen, we should order the networks in the network class and the corresponding functions in the function class according to this classification, starting with the least complicated ones. We shall call this the building of an *arsenal.* Networks to which, in the network class, equivalent networks of lower complexity exist, should not be incorporated in the arsenal.

2.6. *Network elements.* — We are in particular interested in the most general network classes. These result if no restrictions are imposed on the configuration and on the distribution of the components in it. A class of components has, however, to be given. Classical circuit theory considers R, L, C and the ideal transformer as the components, which looks somewhat arbitrary. We can try to develop classes of components in a systematic way by starting from the concept of classes of systems (black boxes) characterized by some general properties (e. g., passive systems characterized by linear equations with constant coefficients). We can consider the « simplest » of these systems as components and can call them network elements, *by definition.* The qualification « simplest » can be given a meaning if we introduce a classi-

(1) This corresponds to Darlington's « price list » (2).

fication as mentioned in subsec. 2.5. From this point of view a network element is defined by relations between the currents and voltages at the terminals and not by the physical means required to realize it. It is thus an ideal element, that can only be approximately realized. The class of network elements thus found can be called *complete*, if any system of the system class can be realized as a network composed of them.

3. — Results and open questions

For most of the subsections of sec. 2 it is not difficult to enumerate a number of results, but this will not be of much use for our purpose, unless the results are grouped together and are given in such a broad sense that they cover the whole field in a small number of pages. The author has not been able to perform this task and so this may be considered itself as an open question. Whereas the secs. 1 and 2 aim to give a full survey of subject and taks of circuit theory, this section contains only some casual remarks, most of them related to linear systems, that depend largely on the preference and fortuitous knowledge of the author.

3.1. *General properties.* — Attention is drawn to the concept of *inter-reciprocity* introduced and used by Bordewijk (3) and applicable both to reciprocal and to nonreciprocal linear networks. Two two-ports are said to be inter-reciprocal if their impedance matrices are each others transpose.

3.2. *Analysis.* — Recently introduced tools are the *signal flow graphs* investigated by Mason (4), particularly useful for the analysis of linear feedback systems.

Nonlinear networks can be classified in those having small nonlinearities and thoses having large ones. The characteristics of the first category can often be approximated by power series, and useful results can be obtained by limiting the series to a few terms. The characteristics of the second category can often be approximated by broken lines or broken surfaces consisting of a number of linear parts.

3.3. *Synthesis.* — The ports of a transformer can be considered insulated from each other. Therefore, if the given class of components contains the transformer, for the realization of network

classes with ports we can use networks of which the ports are insulated. It is then unnecessary to consider separately network classes with other groupings of the terminals, for these can always be derived from networks with ports by connecting in an appropriate way terminals belonging to different ports. A table of synthesis problems solved, as regards points 1-5 of subsec. 2.3, is given by Darlington (5). The problems are solved for general (1) n-ports composed of R's, L's, C's, and transformers, and also for those composed of R's, L's, C's, transformers, and gyrators (6). The synthesis of network classes composed of R's, L's, and C's, without transformers and gyrators, is solved only for two-poles. For the next simple case, the three-pole composed of two kinds of R, L, C, the problem is solved only for the transfer function.

3.4. *Requirements.* — The requirements put to networks to be used in radio and allied apparatus should in principle be derived from information theory. So it may be asked from information theory to formulate the requirements in such a manner that the concepts of information theory do not enter in them.

3.5. *Arsenal.* — Networks composed of R's, L's, C's, transformers, and gyrators can be classified according to the number of ports, the order, and the rank. By *order* of an n-port (7) (also called *degree* (8)) is meant the order of the differential equation of the free oscillations of the system formed by connecting the ports to the ports of a reactanceless n-port. By *rank* of an n-port is meant the rank of the hermitian part of the impedance matrix on the imaginary axis. The minimum number of reactances or resistances sufficient to realize an n-port is equal to the order or the rank, respectively. An n-port can be realized by a network containing both the minimum number of reactances and the minimum number of resistances (6). A class of n-ports of given order and rank is determined by a certain number of independent parameters. The minimum number of network elements sufficient to realize such an n-port class is equal to the number of independent parameters. A one-port class of given order and rank can be realized by a single network containing both the minimum number

(1) With « general » is meant that no restrictions are imposed on the configuration and on the distribution of the components in it.

of reactances and the minimum number of resistances (one or zero) and also the minimum number of elements (9). It is conjectured that this holds for n-ports. These networks do not contain the minimum number of gyrators. The minimum number of gyrators is investigated by Carlin (10) and by Oono and Yasuura (6).

For networks composed of R's, L's, and C's, or two kinds of them, the above classification is not very appropriate. For example, the realization of a one-port class of given order by the Bott and Duffin (11) or related procedure leads to networks containing more than the minimum number of elements. As a result a number of relations exists between the element values. If this number of elements is available, then, from the application point of view, there is no reason to restrict to element values satisfying the mentioned relations, for by dropping this condition a more extensive class of one-ports can be realized. It is to be expected that requirements resulting from application can then better be met. A more natural classification seems therefore a classification according to the number of elements, or to the number of resistances and the number of reactances separately.

Nonlinear networks whose characteristics consist of broken linear surfaces (cf. subsec. 3.2), can be classified according to the number of linear parts of which the characteristics are composed. The simplest class of networks according to this classification is the class of which the characteristics are composed of one linear part, i. e., the linear networks.

3.6. *Network elements.* — The task of developing a complete class of linear constant passive network elements can be performed by means of the classification mentioned in subsec. 3.5. The « simplest » systems are the one-ports of order and rank one, the one-ports of order one and rank zero, and the two-ports of order zero and rank zero. This leads to R, L and C, transformer and gyrator, respectively (12). The completeness of this class of elements in connection with the linear constant passive systems follows from the investigations of Oono and Yasuura (6).

By considering more general classes of systems than the class of linear constant passive systems, and looking for the « simplest » systems in these classes, we can try to extend the class of network elements. From a physical point of view we may restrict the investigations to the class of constant passive systems, for the cause of

variability and activity is always outside the elements in some energy source. Transistors and ferromagnetic coils are in themselves constant and passive, but they are no longer linear. It is by investigating, in nonlinear systems, small oscillations superposed on a d. c. or a. c. fundamental state that linear variable and linear active systems arise, but the physical systems behind these are nonlinear constant passive. A task is therefore to investigate the simplest nonlinear constant passive systems and to consider these as nonlinear network elements, and to try to develop in this way a class of network elements by which any constant passive system can be realized.

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Chairman Sub-Commission VI-2.

June 1957

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Sub-Commission VI.3

Antennas and Waveguides

N° 262. — REPORT OF THE WORKING GROUP ON MICROWAVE OPTICS

Part I : *General Remarks on Microwave Optics* (Dr. Roy C. SPENCER, *Chairman*).

Part II : *Microwave Optics and Fourier Methods* (Dr. Roy C. SPENCER).

Part III : *Some recent Researches in Optics and Electromagnetic Theory* (Dr. Emil WOLF).

Part IV : *The Comparison of noise in Radio and Optics* (Prof. A. BLANC-LAPIERRE).

Part V : *Comparison of Communication Theory in Circuits, Optics, and Radio* (Mr. Francis J. ZUCKER).

Part I

GENERAL REMARKS ON MICROWAVE OPTICS

(Roy C. SPENCER, *Chairman*)

A. — INTRODUCTION

The present « Working Group on Microwave Optics » was formed August 1954, at the XIth General Assembly of U.R.S.I. at the Hague. It is a continuation of the former U.R.S.I. Sub-Commission VIc on Microwave Optics which was formed August 1952, at the Xth General Assembly at Sydney, Australia.

The report of Commission VIc to the XIth General Assembly was published in Trans. IRE PGAP (1), with the exception of a paper by Professor Blanc-Lapierre on « Information Theory and Optics » and a paper by A. E. Heins and S. Silver on « The Edge Conditions and the Field Representation Theorems in the Theory of Electromagnetic Diffraction ». Reference 1 includes a history of the meetings on Microwave Optics up to 1954 as well as papers by H. Bremmer and E. Wolf. Reprints are available.

The present members of Commission VIc, with the exception of F. J. Zucker, were also members of the previous group. The current roster consists of the following :

R. C. SPENCER (*Chairman*) : Sylvania Electric Products Inc., Waltham, Massachusetts, U.S.A.

A. Blanc-Lapierre : Faculté des Sciences d'Alger, Algiers.

H. Bremmer : Philips, Eindhoven, the Netherlands.

E. Wolf : University of Manchester, Manchester, England (now on leave at New-York University).

F. J. Zucker : U. S. Air Force Cambridge Research Center, Hanscom Field, Bedford, Massachusetts, U.S.A.

B. — Program

1. — *Initial Plans for the Period Aug.* 1954 *to Aug.* 1957.

The following recommendations were made at a meeting of the Working Group on Microwave Optics held on August 28, 1954.

« (*a*) To extend the Working Group on Microwave Optics for a period of three years to the XIIth General Assembly.

(*b*) To expand the present report and publish the results in the form of a monograph entitled « Microwave Optics and its Relations to Other Fields ». This is to serve as a guide to the radio engineer and physicist in the choice of the techniques available for solving design or analysis problems in Microwave Optics. The analogies to related fields will be stressed as well as the bounds of validity for the various techniques. »

2. — *Modified Goal of the Working Group.*

Pressure of other duties delayed preparation of the monograph to such extent that time was not available to complete it. Therefore, it was decided to bring up to date the list of symposia, review papers, etc., that was started in the earlier report, and to supplement this with contributions from working group members on topics of special interest suitable for discussion.

C. — Relation of microwave optics to other fields

The relationships between microwave optics and other fields is illustrated by the topological diagram of Figure 1. Microwave optics is strongly linked with the *physical* fields of geometric optics, physical optics, and electromagnetic theory, and with the electronic fields of circuit theory, communication theory, and/or information theory. Microwave optics is also strongly linked to the operational methods of mathematics either through the Fourier integral approximation to the diffraction patterns of antenna

apertures, or the Laplace integral formulation of transients in waveguides.

D. — Symposia and meetings

The following symposia and meetings either feature or include microwave optics. Eight of the nine meetings listed have been held since the XIth General Assembly.

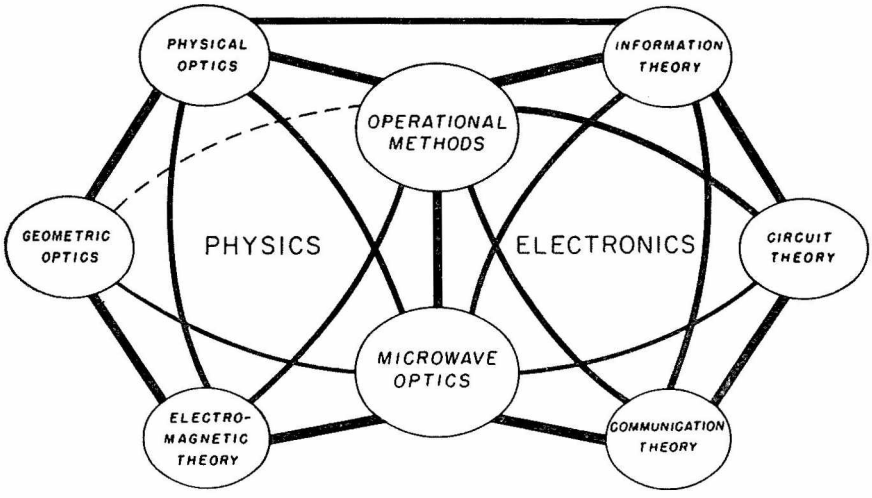


Fig. 1. — Relationships between microwave optics and other fields.

1. — *Symposium on Microwave Optics*, McGill University, Montreal June 22-25, 1953.

This was organized as a result of the formation in 1952 of the original U.R.S.I. Commission VIc on Microwave Optics. The Proceedings of the symposium are to be published by the U. S. Air Force Cambridge Research Center, Hanscom Field, Bedford, Massachusetts, U. S. A., in late fall of 1957. (Reviews of this symposium were made by George Sinclair and Samuel Silver in Trans. IRE AP, Vol AP-1, Oct. 1953, pages 58-60).

Other reviews were by E. Wolf (*Nature*, October 3, 1953) and by Morris Kline (*Physics Today*, March 1954). H. Bremmer in Part II of reference 1 gives a detailed review of the McGill Symposium. Unfortunately, there are a few omissions and typographical errors in the references.

2. — The *Florence Meeting on « Problems in Contemporary Optics »*, September 10-15, 1954.

This assembly incorporated sessions on classical optics, non-classical optics (including Microwave Optics), and information theory as applied to optical systems. The Proceedings of the Florence Meeting were published by the Istituto Nazionale di Ottica, Firenze (Florence) in 1956.

3. — The *University of Manchester Symposium on Astronomical Optics*, April 19-22, 1955.

The purpose of this symposium was to bring together specialists in optical and radio astronomy. Of the papers related to Microwave Optics, there were several on diffraction theory, antenna design, and information theory. The Proceedings were published in 1956 by the North Holland Publishing Co., Amsterdam. Interscience Publishers in New-York are agents in the U. S. A.

4. — *Symposium on « Electromagnetic Wave Theory »*, University of Michigan, June 20-25, 1955.

This symposium, sponsored jointly by Commission VI of U.R.S.I. and the University of Michigan, covered many of the advanced topics of electromagnetic theory as well as antenna theory and microwave optics. The Proceedings were published as the July 1956 issue of the *IRE Transactions on Antennas and Propagation*, Vol. AP-4, No 3. Copies of this issue are now out of print.

5. — *Panel on Radio Astronomy*, National Electronics Conference, Chicago, October 1955.

This was a half-day panel discussion by several participants who reviewed various aspects of research in radio astronomy, including contributory fields of optical astronomy and antenna design. The papers appear in the Proceedings of the National Electronic Conference, 1955, Vol. II, published in 1956 by the National Electronics Conference, Inc., Chicago, Illinois, U. S. A.

6. — *Colloque International sur la « Propagation des Ondes »*, September 17-21, 1956.

This symposium, organized by the French National U.R.S.I. Committee, considered all aspects of radio propagation problems. A communication by V. A. Fock concerning Russian work on

extensions of the theory for the diffraction around a sphere to other surfaces in terms of their curvatures, should be noticed. The proceedings of this Symposium were to appear in May 1957 in both « L'Onde Electrique » and « Annales des Télécommunications ».

7. — *George Washinglon University Symposium on Optics and Microwaves*, November 1956.

This was a tutorial symposium aimed at bringing together people interested in optics and microwaves. A wide variety of topics were discussed. They included infrared, ultraviolet, high temperature reactions in shock waves, communication between interplanetary space ships, communication theory applied to optical lens design, and optical lens design applied to microwave antenna design. Research on the optics of the human eye was reviewed and included a study of the Stiles-Crawford effect in the rods and cones, together with analogous experiments on 3 cm wavelength microwave dielectric end-fire antennas. The abstracts of the papers were incorporated in the Symposium Program ; however, as most of the subject matter appears elsewhere in the literature, no plans were made for publishing the actual papers.

8. — *Boston University Symposium on Communication Theory and Antenna Design*, January 9, 10, 11, 1957.

This meeting was sponsored jointly by the Air Force Cambridge Research Center and by Boston University. This was also a tutorial symposium, but one which had the specific goal of surveying in a logical manner the mathematical background of communication theory ; its applications to Electronics, to Optical Lens Design, and to Radio Astronomy ; and the current and projected application to antenna design.

The symposium, together with its Proceedings which have been published by the Air Force Cambridge Research Center, should stimulate further study in this field.

9. — *Conference on « Ultra High Frequency Circuits and Antennas »*, organized by the Société des Radioélectriciens, scheduled for October 21 to 26, 1957, in Paris.

Papers under the following general classifications have been solicited. (For further details address correspondence to : 10, Avenue Pierre, Laroisse, Malakoff (Seine).)

(1) Circuit theory relating to waveguides and aerials.

(2) Waveguides and lines.

(3) Waveguide components.

(4) Properties and use of anisotropic materials (ferrites).

(5) Radiating aperture antennas.

(6) End-fire radiating antennas.

(7) Special purpose antennas and antenna measurements.

E. — New books that include microwave optics

F. E. Borgnis and C. H. Papas, *Randwertprobleme der Mikrowellenphysik*, Berlin ,1955.

Max Born and Emil Wolf, *Principles of Optics* (Electromagnetic Theory of Propagation, Interference and Diffraction of Light), Pergamon Press. To be published in the near future. This is based on Max Born's *Optic* but has been completely rewritten with much new material.

Nathan Grier Parke III., *Guide to the Literature of Mathematics and Physics*, Second Edition, New-York ; Dover Publications Inc., 1958.

This book is revised from the first edition published by McGraw-Hill in 1947 and includes the technical and scientific books published between 1947 and 1957. (This announcement is made with permission of the author).

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From the Report of Commission VIc to the XIth General Assembly of U.R.S.I. The Hague, August 23 to September 3, 1954. Published in *Trans. I.R.E., P.G.A.P.*, October 1955. (Reprints are available through R. C. Spencer).

Part II

MICROWAVE OPTICS AND FOURIER METHODS

(Dr. Roy C. Spencer)

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A. — Introduction

The Fourier integral is often used as an approximation to the physical optics diffraction integral in problems where microwaves are scattered from metallic shaped objects or transmitted from broadside antennas. C. J. Bowkamp (1) has published a review article referencing 500 papers published in the period between 1940 and 1954.

B. — Application to scattering

The application of physical optics to the calculation of scattering cross-sections shows that this approximation has wide variation in accuracy. For example, both the physical optics and the geometric optics approximations yield the correct scattering cross-section, πR^2, for a sphere with a very large D/λ ratio. However, physical optics fails to predict the period and amplitude of the oscillations about the value πR^2 with variation in D/λ. This is caused by « surface waves », some of which travel half way around the sphere to interfere with the main reflection from the first Fresnel zone. However, in the case of the back scattering from a semi-infinite cone of semi-angle θ, observed on axis, there are no returning surface waves, and the physical optics formula, $\sigma = \lambda^2(\tan^2 \theta)/16\pi^2$, derived by Spencer (2) has been found to be accurate. Although verified experimentally by Sletten (3), its extreme accuracy was not realized until after extensive investigations by Felsen (4), and by Siegel, Crespin, and Schemsted (5). Even then, it was found that while it was correct for electromagnetic waves, it was in error for acoustic waves.

C. — Application to antenna patterns

The Fourier integral is considered to be a good approximation to the diffraction pattern of an antenna. It is particularly good

for two-dimensional broadside antennas with diameters of many wavelengths.

The usefulness of the Fourier integral stems partly from such properties as series expansion and the convolution theorem. But such properties have been shown to be those of a more general class of linear operators (6) which include (*a*) the Laplace transform when the input function is e^{pt}, and (*b*) the Fourier transform when the input is the plane wave e^{-iux} or $e^{-i(ux+vy)}$.

The Laplace transform has been in general use in circuit analysis, but recently the Fourier transform has become popular (7). It is also very useful in the inversion of X-Ray diffraction data (8). These diverse applications are mentioned because knowledge of analogous methods used in other fields is often helpful.

This author has reviewed many of the Fourier techniques as they apply to antenna pattern analysis (6, 9, 10). In general, any obvious operation that can be carried out on the Fourier integral, $g(u) \propto \int f(x)e^{iux}dx$, will result in a technique useful under certain circumstances. Such techniques are : integration by parts, differentiation under the integral sign, and expansion of e^{iux} in a power series.

D. — Communication theory applied to antenna scanning

It is known that the power antenna pattern is the Fourier transform of the autocorrelation of the antenna aperture. This autocorrelation is the spacial frequency response of the antenna and is termed the « transfer function ». A series of transfer functions obey the multiplication law, so that their significance and usefulness is analogous to that of transfer functions in the communication theory of circuits.

Much work has been carried out, both in Europe and America, on communication theory as applied to optical apertures. This work has been summarized in a set of lecture notes by Edward L. O'Neill (11). Several of the researches which have been inspired by applications to radio astronomy are those by Arsac (12), Bracewell (13), and Ratcliffe (14). These references are included here because they combine Fourier methods and micro-waves.

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Case 1 $1101 \times 1011 = 1113111$

Case 2 $1100101 \times 1010011 = 1111114111111$

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Part III

SUMMARY OF A LECTURE ON SOME RECENT ADVANCES IN OPTICS AND RELATED FIELDS

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The purpose of this lecture is to report on some of the more interesting developments which have taken place in light optics and in related fields within the last few years and which have a bearing on optics of microwaves. The following topics will be reviewed :

1. — Perfect Optical Systems

Optical systems which image stigmatically two surfaces onto each other are of considerable practical interest. Best known of these is the Maxwell fish-eye and the Luneberg lens. In the last few years G. Toraldo di Francia and R. Stettler have discovered other types of perfect systems, some of which may be regarded as a direct generalization of the two systems mentioned.

2. — Geometrical Theory of Diffraction

In a report presented to the General Assembly in The Hague in 1954, attention was drawn to the fact that some of the laws of geometrical optics appear to have analogy in rigorous diffraction theory. An important contribution in this direction was made by J. B. Keller who formulated a « geometrical theory of diffraction ». In this theory the concept of a diffracted light ray is introduced and with each such ray an appropriate field is associated. The propagation of the field along each diffracted ray obeys the same laws as the field along a ray of geometrical optics.

3. — Scalar Diffraction Theory of Optical Imaging

An important paper by J. Focke gives a rigorous extension of the principle of stationary phase to double integrals of the form that occur in the scalar diffraction theory. With its help, Focke derived the complete asymptotic expansion (in the wave number) of these integrals. The same results were later obtained independently by a different method by D. S. Jones, M. Kline and N. Chako. The results make it possible to obtain a clear understanding of the significance of the Debye-Picht diffraction integrals and have a bearing on many diffraction problems.

An old problem in the scalar diffraction theory is the question of detailed phase behavior of the phase near the geometrical focal plane. This has recently been solved by E. H. Linfoot and E. Wolf by an extension of Lommel's classical analysis. The results are in broad agreement with recent measurements on 1.25 cm wave lengths carried out by G. Bekefi and M. P. Bachynski. These authors also give measurements of the distribution of the electric energy in the image in the presence of various aberrations and are in good agreement with results of the Zernike-Nijboer theory.

4. — Diffraction in Wide Aperture Systems

Recent papers by R. Burtin, B. Richards and E. Wolf, and by J. Focke show the structure of the diffraction image in systems of wide angle aperture. For such cases the usual scalar diffraction theory is inadequate and other techniques had to be used. Images in polarized as well as unpolarized light are considered.

5. — Analytic Signals

The concept of an analytic signal, which was introduced by D. Gabor in 1946, is playing an increasingly important part not only in communication theory but also in optics. This concept will be explained and the relevant literature quoted.

6. — Reciprocity Inequalities (« Uncertainty Relations »)

Several papers were published dealing with the question of defining the effective duration Δt of a signal and its effective frequency range $\Delta\nu$ in such a way that a rigorous inequality of the type $\Delta t \Delta\nu \geq a$ is obtained, where a is a constant. As was first pointed out by D. Gabor in 1946 the usual formulation of the inequality is unsatisfactory when the signal is represented by a real function. Recent contributions are due to D. Lampard, I. Kay and R. A. Silverman, and to E. Wolf.

7. — Correlation Problems

Considerable progress has been made in recent years in statistical optics. A general theory of partial coherence has now been formulated (P. H. Van Cittert, F. Zernike, H. H. Hopkins, A. Blanc-Lapierre and P. Dumontet, E. Wolf, D. Gabor, H. Gamo). Application of the theory to specific problems were made by J. Dyson, S. Slansky, W. H. Steel.

Similar techniques have recently been applied by M. J. Beran to some problems relating to scattering of radiation by the ionosphere, rough surfaces, etc. It may be possible to treat by these techniques in a unified manner many of the problems reviewed recently by J. A. Ratcliffe in his article in *Reports on Progress in Physics*, 1956.

8. — Spatial Frequencies and Response Functions

Rapid progress has also been made in the analysis of the performance of optical systems from the standpoint of response to spatial frequencies. The basic ideas, due to Duffieux, are being fully explored. Many workers, notably A. Blanc-Lapierre, E. H. Linfoot, G. Black, H. H. Hopkins, M. De, E. L. O'Neill, B. G. Parrent and C. J. Drane, and H. Gamo studied response functions for coherent

or incoherent illumination, in the presence of various aberrations. Interesting generalizations to partially coherent illumination are due to H. H. Hopkins and P. Dumontet.

Part IV

CONTRIBUTION TO THE STUDY OF NOISE IN OPTICS

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(*Translation*)

Summary. — A comparison is made between the properties of « optical noise », due to the granularity of photographic emulsions, and those of radioelectric noise.

Introduction

Much work has been done in order to apply information theory to Optics (1). As in Radioelectricity, the « capacity » of an optical transmission channel, i. e. the maximum quantity of information that this channel may carry per second and per unit surface of the optical object, is limited by a number of random factors which are playing the role of an « optical » noise. As an example we may quote : a fluctuating illumination of the object, an accidental variation of the scattered light, a random change in the pupil transparence due to microscopic random defects, photonic fluctuations in the observing device, etc. Much attention will be given here to a particular case ; we shall suppose that time is not occurring, the object being motionless and illuminated by means of a monochromatic radiation ; on the other hand we shall be concerned with one factor : the granularity of the photographic emulsion.

Some of the above considerations have of course a much more general bearing, as they are valid in any circumstance when irregularities in transparence are involved (fig. 1) illustrates two outermost examples.

In fig. I*a*, irregularities of transparence occur in the plane of a pupil diffracting at infinity.

In fig. I*b*, the above mentioned plane of random irregularities coincidates with a focal plane.

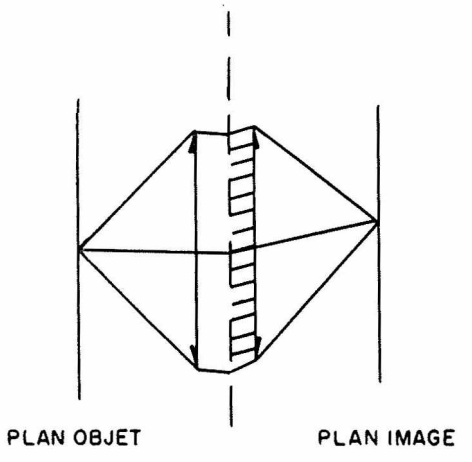


Fig. 1*a*

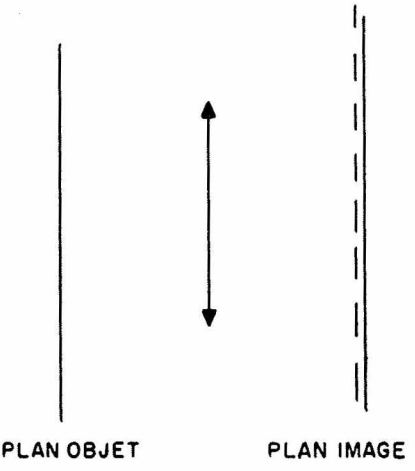


Fig. 1*b*

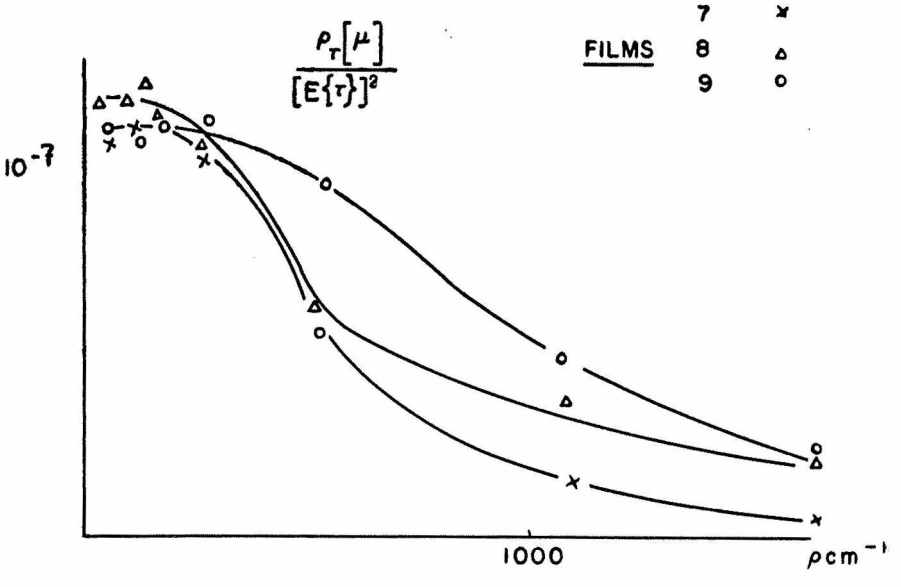


Fig. 2

In the first case, these irregularities are perturbing the gain of the linear filter, equivalent to the optical device ; with suitable conventions the Fourier transform of the object is multiplied by

the transparence. In the second case, it is the object itself, which is multiplied by the transparence.

Defining the statistical properties of the random transparence involved in the problem is already worth of interest. Attention will be given to a photographic film, in view of comparing optical noise with its classical equivalent in radioelectricity.

A. — Physical origin

1. — *Radioelectricity.*

(*a*) Shot effect, and thermal agitation (microscopic phenomena, with respect to the time constants of our measuring devices).

(*b*) Scintillation effects (whose time constants are consistent with our scales).

2. — *Emulsion granularity.*

Granularity is due to random distribution of silver agglomerates in the gelatin. These agglomerates can be detected with a microscope.

B. — Mathematical Representation and Statistical properties

1. — A noise voltage can always be represented by a real random function of the time X (t).

A film will be considered as a two dimensional variety. Its transparence can be defined in terms of two coordinates x, y (coordinates of point M) on the film surface. Let us consider a film processed after uniform exposure. With respect to the complete set of « microscopically identical » films, the transparence is a random function of point M.

We have to consider either *complex transparence* θ (M), called *transparence in amplitude*, or *real transparence* $\tau(M) = |\theta|^2$, called *transparence in intensity.*

X(t) is a stationary random function of the time. Similarly, for a film processed after uniform exposure (no signal), θ and τ are stationary random functions of point M.

2. — *Second order properties.*

Let the harmonic representations :

$$\theta(M) = \int_{[\vec{\nu}]} e^{2\pi \vec{\nu} \vec{M}} d\,\Theta[\vec{\nu}] \tag{1}$$

and

$$_{\tau}(M) = \int_{[\vec{\nu}]} e^{2\pi \vec{\nu} \vec{M}} dT(\vec{\nu}) \tag{2}$$

(here $\vec{\nu}$ is the frequency (two dimensional quantity with components ν_1 and ν_2), $d\theta(\vec{\nu})$ and $d\tau(\vec{\nu})$ are the random increases of θ and τ over two $d(\vec{\nu})$ in the frequency plane).

Owing to the stationarity, we have for two separate $d(\vec{\nu})$ and $d(\vec{\nu})$

$$E\{\, d\theta(\nu) d\Theta^*(\nu) \,\} = 0 \tag{3}$$

$$E\{\, dT(\nu) dT^*(\nu') \,\} = 0 \tag{4}$$

E being the symbol of the mathematical expectation.

The spectral densities of θ and τ are defined by :

$$E\{\, |d\Theta(\vec{\nu})|^2 \,\} = \rho\theta(\vec{\nu})\, d(\vec{\nu}) \tag{5}$$

$$E\{\, |dT(\vec{\nu})|^2 \,\} = \rho_{\tau}(\vec{\nu})\, d(\vec{\nu}) \tag{6}$$

with $d(\vec{\nu}) = d\nu_1 d\nu_2$.

The correlation functions are :

$$C_{\theta}(\vec{M}) = E\{\, \theta(\vec{N})\ \theta^*(\vec{N} - \vec{M}) \,\} = \int_{[\vec{\nu}]} e^{2\pi i \vec{\nu} \vec{M}} \rho_{\theta}(\vec{\nu})\, d(\vec{\nu}) \tag{7}$$

$$C_{\tau}(\vec{M}) = E\{\, _{\tau}(\vec{N})\ _{\tau}(\vec{N} - \vec{M}) \,\} = \int_{[\vec{\nu}]} e^{2\pi i \vec{\nu} \vec{M}} \rho_{\tau}(\vec{\nu})\, d(\vec{\nu}) \tag{8}$$

3. — *Comparison with noise $X(t)$.*

(*a*) The shot effect and thermal agitation are macroscopically correlated phenomena. Their spectra are uniform (white). For radioelectric frequencies the spectral density is independent of ν.

(*b*) The scintillation effect is a microscopically correlated phenomenon and its spectral density varies with ν. The same can be said of the optical noise, arising from film granularity. In the range of the object's spatial frequencies, transmitted through a microscope $\rho\theta(\vec{\nu})$ and $\rho\tau(\vec{\nu})$ actually vary with $\vec{\nu}$.

For θ and τ we have to consider the question of isotropy, which does not arise for $X(t)$.

For the second order average values, isotropy occurs if the correlation function depends only on $|\vec{M}|$ or (equivalent condition) if the spectral density ρ depends only on $|\vec{\nu}|$. As far as θ is concerned, Croce and Mrs Marquet have shown evidence of anisotropy in film emulsions. On the other hand, in the case of τ, no definite anisotropy has been found and the same authors consider that generally τ is isotropic. We shall make here this assumption.

Let $|\vec{M}| = r$ and $(\vec{\nu}) = \mu$; $rC\tau(r)$ and $\mu\rho_r(\mu)$ are then reciprocal Hankel transforms. Some questions arise form the isotropic character of $\tau(M)$ which have been recently studied by P. Faure (3).

The mathematical expression of the functions $C\tau(r)$ leads to the fact that the class φ_2 of the correlation functions $C_2(r)$ of the real bidimensionnal, isotropic and stationary random functions $X(M)$, is more restrictive than the class φ_1 of the correlatoin functions $C(|X|)$ of the stationary random functions $X(x)$. It is obvious that any function of φ_2 belongs to C_1 because C_2 $(|X|)$, is the correlation function of $X(x)$ (x and y being the coordinates of M) but the opposite is not true. For example $(1 - x^2)/(1 + x^2)^2$ belongs to φ_1 (spectral density : $2\pi^2(\nu)e^{-2\pi|\nu|}$) but $(1 - r^2)/(1 + r^2)^2$ does not belong to φ_2.

(d) From the experimental investigation of the spectrum of $\tau(M)$ arises the following problem : let us suppose that we have experimentally defined a real isotropic random function $X(M)$ on the X axis (this is to say that $X(x)$ has been investigated) ; let $C_1(x)$ and $\rho_1(\nu)$ be the correlation function and the spectral density of $X(x)$. From the isotropic character, one or the other of these functions (for $X(x)$ of one variable x) defines the correlation function C_x and the spectral density ρx of $X(M)$; function of two variables. Working on the correlation function, we are led to :

$$C_x(r) = C_1(r)$$

Working on the spectra leads to :

$$\rho_x(\mu) = -\frac{1}{\pi}\int_{\mu}^{\infty} \frac{d}{du}\left\{\rho_1(u^2)\right\}\frac{du}{\sqrt{\mu^2 - \mu^2}} \qquad (10)$$

thanks to (4) and (3).

(*e*) *Distribution functions.* — The above considerations are related only with second order properties. For all practical case in radioelectricity, (X*t*) is a laplacian stationary random function (5); If t_1, t_2 ... t_K are arbitrary time values (K arbitrary) the whole set of random variables $X(t_1)$, $X(t_2)$ ... $(X(t_K)$ satisfy to a Laplace-Gauss distribution with K variables. It does not seem, for the time being, that the properties of the distribution functions associated with $\theta(M)$ or $\tau(M)$, are completely cleared out. To our personal knowledge, no references about $\theta(M)$ are to be found in the literature. Some authors seem to admit that, for a *unique* point M_1,$\tau(M_1)$ should present a gaussian character around E $[\tau(M)]$

C. — Measurement of the Spectral Properties

In radioelectricity, highly selective circuits are generally used in order to determine the spectral density $\rho(\nu)$. Direct reading correlators are more rarely employed.

Concerning the film granularity, a distinction must be made between the methods involving only the spatial aspect of the problem, between the methods involving only the spatial aspect of the problem, (i. e. when time is not involued) and those where the M plane is explored along a curve $M(t)$, described as a function of the time according to a specific cinematics. We are, in this case, concerned with the spectral study of random function of the time.

1. — *Methods involving only spatial arguments.*

(*a*) *Determination of the spectral density* $\rho\theta$. — Croce and M. Marquet (2) have indicated an optical method of harmonic analysis : the film investigated is placed behind an optical device forming an image of a monochromatically illuminated spot on the picture. The intensity distribution in the image plane gives $\rho\theta[\vec{\nu}]$.

(*b*) *Determination of the correlation function* $C\tau$. — Fellgett (6) described a device giving, by photoelectric integration and for a given surface S of the film, the spatial average :

$$\frac{1}{S}\iint_{(S)} \tau(\vec{N})\ \tau(\vec{N}-\vec{M})\ d(\vec{N}) \qquad (11)$$

For S sufficiently large, this value is a good approximation of C_τ provided that the film is uniformely illuminated and that the light

beam crosses it twice at points a and b such that $\overrightarrow{ab} = \overrightarrow{M}$ The total transmitted flux gives the integral (11). H. Zweig (7) mentioned his determinations of correlation functions leading him directly to spectra.

2. — *Methods involving time variables.*

These methods have been used for $\tau(M)$. The random-function spectrum of $F(t) = \tau[M(t)]$ is analysed in placing on the film the curve $M = M(t)$. A correction must be made owing to the fact that the exploring spot is not ponctual. P. Faure (8) showed that $F(t)$ is a stationary random function of the time only if the scanning is linear or circular and performed with a constant speed. In the first case, the spectral density $\rho(x)$ is obtained ; $\rho_\tau(\mu)$ is deduced from it by eq. (10). The study of the correlations on a circle of radius R ; i. e. the study of the correlations for a periodic function F (s), where s is the curvilinear coordinate, will give $C_\tau(r)$ only for $0 \leq r \leq 2R$, but this is practically immaterial if R is sufficiently large. Information on the subject can be found in (8). B. Picinbono and M. Savelli (9), (10) used a linear scanning for obtaining spectra of Super XX films ; fig. (2), extracted from ref. 10, gives the spectral densities obtained by this method.

Remark : What is the relation between ρ_θ and ρ_τ ? This question may be expressed in other words : which relation exists between spectra before and after detection ? The answer is unobtainable if we are considering only the second order properties of ρ_θ. These problems are resolved in radio-electricity because we know that X (t) has a gaussian distribution. Our knowledge concerning granularity are not going so far.

D. — Statistical Models

The noise properties can be interpreted by means of a statistical model in which very short pulses distributed in time with a Poisson law are involved. In the case of granularity, many models have been offered. All of them are rather crude. Let us indicate two models of fairly simple mathematical formalism, and yielding enough to expound some of the various properties of random transparence. B. Picinbono (12) considers opaque circles C_j distributed on a transparent background ; the centres M_j of these circles are supposed distributed with a uniform Poisson density d ;

their radii Rj are random variables satisfying to the same laws and are independent of each other as well as of the centers position. M. Savelli (13) has indicated a similar model offering more possibilities by the fact that each circle is supposed to have a non vanishing transparence, thus allowing the author to take overlapping into account. The author makes the assumption that the transparence T(M) of the point M of the film is h_1 if M is recovered by no circle, and $h_1 h_2^n$ if M is recovered by n circles C_j.

Though imperfect and fairly remote from the physical fine structure, these two models allow interpretations of some of the spectral properties revealed by experience.

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Part V

COMPARISON OF COMMUNICATION THEORY IN CIRCUITS, OPTICS, AND RADIO

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Notes on the Difference Between One-Dimensional Time Filters (Networks), Two-Dimensional Space Filters (Optics), and Three- (or More) Dimensional Space-Time Filters (Antennas)

The following notes are in response to a suggestion by Dr. S. Silver, recorded in Report No 2 by the Working Group on Microwave Optics (21 May 1957), that a survey report be prepared which would form an opening for a discussion at Boulder on a comparison between optics and microwaves. The notes do not constitute such of a survey report, but suggest some relevant material.

A comparison between communication theory techniques in various disciplines seems particularly apropos now that these techniques are being applied to antenna problems. Differences between *time* and *space* filters (that is, filters for time-like frequencies and filters for spatial frequencies) have been discussed in the literature. We are now concerned with a further kind of filter, the antenna, which might be termed a *space-time* filter, because the response of an antenna to both spatial frequencies (radiation pattern) and time-frequencies (network « Q ») is relevant. There is also a dimensional difference between antenna filters and network (*one*-dimensional) or optical (*two*-dimensional) filters, at least where radar antennas are concerned : radar images specify target range in addition to target location, making the filter *three*-dimensional. If the variation of the radar image with time is an important systems consideration, the filter may be said to be *four*-dimensional. The filter representation of certain kinds of Doppler radar would require even higher dimensions.

In spite of good beginnings, the recent AFCRC — Boston University Symposium on Communication Theory and Antenna Design did not provide a complete frequency domain description

valid for general antenna systems. It did so only for radio astronomy antennas, which are closely akin to optical systems. The application of communication theory techniques to space-time filters, therefore, is a story that has yet to be written.

The following points of comparison between networks, optics, and antennas are listed in this note :

1. Points of Comparison Connected with the « Shift » Property of Linear Systems.
2. Points of Comparison Connected with the Nature of Signals in Time and in Space.
3. Points of Comparison Connected with the Nature of Noise.
4. Points of Comparison Connected with Questions of Coherence.
5. Points of Comparison Connected with Uncertainty Relations.

The list is of course incomplete, and could have been arranged differently.

The discussions that follow are sketchy, except for Item 1. Many of the points that will be raised are discussed in the literature. A useful reference is a paper by Kohlenberg and Cheatham (*Convention Record of the IRE*, 1954).

1. — *Points of Comparison Connected with the « Shift » Property of Linear Systems.*

Linearity implies superposition and proportionality ; the output, $f_0(x)$, of a linear system can then be written as the superposition integral

$$f_0(x) = \int_{-\infty}^{+\infty} h(\xi, x)\, f_i(\xi) d\xi \qquad (1)$$

where $f_i(x)$ is the input and $h\ (\xi,\ x)$ the impulse response of the system. If, in addition to linearity, the « *shift* » property :

$$f_i(x + \overline{x}) \rightarrow f_0(x + \overline{x}) \qquad (2)$$

is satisfied, then we can write Eq. (1) as the convolution

$$f_0(x) = \int_{-\infty}^{+\infty} h(\zeta - x)\, f_i(\zeta) d\zeta. \qquad (3)$$

If all the functions are Fourier transformable, Eq. (3) can be put in the familiar form :

$$\mathrm{F}_0(x) = \mathrm{H}(x)\, \mathrm{F}_i(x), \qquad (4)$$

where $H(x)$ is known as the « transfer » function of the linear system (capitals denote Fourier transforms of the corresponding functions).

If the input and output are random functions, not possessing Fourier transforms but specified by a power spectrum, then an equation closely analogous to Eq. (4) holds, also involving the system transfer function.

The point to be made here is that a linear system cannot be uniquely described by a transfer function *unless* the shift property, Eq. (2), holds. This property asserts that if an input occurs at x_0 and the response at $x_0 + \bar{x}$, then an input at x'_0 will be followed by an output shifted through the same (time or distance) interval $\bar{x}$. In the network case, systems having this property are called « stationary ».

How do networks, optical systems, and antennas compare with respect to the shift property ? The remarks which follow are taken from the « Summary Comments » in the Proceedings of the Symposium on Communication Theory and Antenna Design.

In the *network* case, the parameters specifying a system (black box) are usually stationary in time, that is, the shift property holds and a unique transfer function can therefore be defined. An important exception is formed by the so-called time-varying networks recently discussed by Zadeh and others, which violate the shift property and for which Eq. (4) cannot therefore be written.

In an *optical* system, each point in the object space corresponds to the input terminal of a linear system, and each point in the image space corresponds to its output terminal. Since both object and image are distributed over space, each optical system is really characterized by an infinite number of outputs and inputs. Each of these object-image pairs constitutes a linear system with constant coefficients, because Maxwell's equations, which govern the system, are linear (except for the unimportant case in which the constitutive parameters are functions of the field intensity). The constant coefficients themselves, however, depend on the position in space of the object-image pair. Thus the set of black boxes connecting each object-image pair is characterized by different impulse-response functions so that $h(\zeta, x)/h(\zeta - x)$. If the object point is shifted by an amount $\bar{x}$, the corresponding impulse response will

depend not only on $\bar{x}$ but also on the position of the original object point. This property coincides with what we ordinarily call optical aberration. In the general optical case, then, the shift property does not hold and the Fourier transform relation, Eq. (4), cannot be written.

If the aberrations vary slowly enough as the input terminal explores the object surface (small objects), the input response remains reasonably constant over a limited region of space, and the shift property holds approximately. A paper by Dumonted (*Optica Acta* 2 : 53, 1955) explores the limits within which this approximation is good. Linfoot and Fellgett (*Royal Sec. Lond. Phil. Trans.*, 331 : 247, 1955) define a transfer function for each of these limited regions in space, so that Eq. (2) holds within each region. Our conclusion, then, is that in optical systems, Eq. (4) is valid only in a small though important class of cases.

In contrast, the antenna engineer faces a more favorable situation : the shift property, and therefore Eqs (4), are almost invariably applicable. Note that an antenna has no image space unless it scans. In the static case, the antenna system automatically satisfies the spatial shift property (and it is also stationary in time, unless the propagation conditions vary as a function of time). When the antenna scans, its output voltages generates an image space. There are two basic ways of scanning : either the primary feed moves alone or the antenna moves as a whole. (For the present purpose, electronic scanning may be classed with the first case). If the primary feed moves, we have a situation closely analogous to optics, except that the aberrations in the usual microwave system are much smaller than in an optical system (smaller aperture in terms of wavelengths), and that they also change more slowly as a function of displacement. The shift property therefore holds.

If, on the other hand, the primary feed is held in a fixed position and the antenna scans as a whole, then only a single object-image pair is involved, the physical constants of the black box do not change, we are dealing with a single transfer function, and the Fourier transform relation, Eq. (4), holds without approximation. Note that it is immaterial whether the antenna scan is obtained by linear displacement (as in ground mapping) or by rotation

(as in search), so long as the distance between the antenna and the object plane or sphere remains constant.

2. — *Points of Comparison Connected with the Nature of Signals in Time and in Space.*

2.1. *Asymmetry of the time functions.* — Output can only depend on past values of input. One might list the restrictions imposed on the synthesis of time filters by the requirement that the impulse response, $h(t)$, be zero for t 0. For example : the spectrum of a time signal must be factorable to be a solution of the Wiener-Hopf equation in the design of linear time filters, while there is no such restriction on spatial signals (objects).

2.2. *Minimum error in presence of noise.* — A network can be designed to reproduce input messages with a time delay. The longer the delay, the smaller the error in presence of noise. In optics and in the spatial aspect of antennas, the delay does not enter and the minimum error is a uniquely defined quantity corresponding to the irremoveable error for infinite time delay in networks.

2.3. *Physical significance of the frequency plane.* — In network theory, the frequency domain is a purely mathematical concept. In certain spatial systems, there is a physical frequency plane. This is true of systems that are coherent, monochromatic, and in which the aperture distribution is accurately described as the Fourier transform of the image. Consequences of the existence of a physical frequency plane : coherent optical filters are easier to construct than network filters, sharp cutoffs are natural in optics, and optical filters are inherently band limited since the physical frequency plane is bounded by a physical aperture.

2.4. *Real or complex nature of input.* — Time signals are always real.

For incoherent optical systems, $h(x, y) > ,0$, that is, the zero-frequency component is always passed (severe restriction on filter synthesis).

In coherent optical systems, the input can be complex ; the phase contrast microscope, for example, can be said to make the imaginary part of an object visible.

When the time element is introduced into spatial systems,

care must be taken to express the input signal in terms of measurable quantities. As Wolf has pointed out, optical signals ought not to be expressed as $F_i(t)$, since only certain averages over time intervals large compared to l/ν can be measured. This also holds for radar, with the further restriction that the time interval must be small compared to the shortest distance over which target motion should be discernible, divided by the target velocity.

3. — *Points of Comparison Connected with the Nature of Noise.*

Professor Blanc-Lapierre has promised a paper on this subject. The discussion could be grouped around the following points :

a) Additive noise (the usual case in networks).

b) Noise that is mutually exclusive with the input signal (object in noisy optical background).

c) Modulated noise. The noise representing film graininess, for example, is a modulation with film grain as a noise-like carrier.

The discussion could also focus on the most typical forms of the noise spectrum in networks, optics, and antennas.

4. — *Points of Comparison Connected with Questions of Coherence.*

Dr. Wolf, according to Report No. 2 by the Working Group on Microwave Optics, has promised to summarize this subject.

In these days of space — and frequency — diversified antenna systems, intensity fluctuations and coherence in polychromatic fields have become topics of practical interest. It is useful, in the antenna case, to distinguish between coherence in time and in space. A dipole illuminated by a large source consisting of randomly phased radiators receives incoherently due to a *time*-averaging process. *Space*-averaging is less obvious. Consider a rough ground illuminated from above, or a ground glass plate illuminated from behind. A dipole sampling the Rayleigh-distributed field of this diffuser will *not* receive incoherently (even if the output signal is averaged in time). What we require is a large collecting aperture (dish). It smoothes out the Rayleigh-distributed field, and thus produces space-like incoherence.

5. — *Points of Comparison Connected with Uncertainty Relations.*

(*a*) *Networks.* — Gabor has discussed an uncertainty relation, applicable to networks, of the form $\Delta t \; \Delta\nu > p$, where Δt is the

coherence time, $\Delta\nu$ the effective bandwidth, and p a constant of the order of unity.

(*b*) *Optics.* — In a very recent paper, Wolf has examined the precise conditions under which Gabor's inequality holds, and extended it to optics by defining Δt in terms of the autocorrelation function of the input, and $\Delta\nu$ in terms of its power spectrum. Both functions have the virtue of being directly measurable in optics.

(*c*) *Radar.* — Siebert has worked on uncertainty relations in radar (Transactions of the IRE Professional Group on Information Theory, October 1956). There is need for further work in this area before a comprehensive survey can be written.

Collaboration with the C. C. I. R.

The Plenary Assembly of the C.C.I.R. held in Warsav in 1956 requested the collaboration of U.R.S.I. for the following topics interesting the activities of Commission VI.

Report nº 46. — Temporal variations of ground-wave field strength.

Question nº 125 (II). — The usable sensitivity of radio receivers in the presence of quasi impulsive interference.

Question nº 137 (V). — Measurement of field strength in the neighbourhood of obstacles.

Study Programme nº 86 (III). — Communication Theory.

The Plenary Assembly drew also the attention of the Commission to the following topics :

Recommendation nº 165. — Communication Theory.

Recommendation nº 166. — Unit of Quantity of Information.

Question nº 133 (III). — Communication Theory.

The text of these topics was published in Information Bulletin nº 100 (*November-December*, 1956).

National Committee Reports

Canada

N° 188. — Report of National Commission VI

Investigation of the properties of slot radiators continues receiving much attention, and some research is being done on two-dimensional arrays of slots of the type described by Broussard (Annales de Radioélectricité, XI, 70, 1956). The theory of very low conductance slots in waveguides is being investigated, particularly the problem of obtaining resonance. Design methods for small annular slot antennas are being developed.

Progress in the theory of diffraction and scattering by dielectric objects is being made. Theories on diffraction by absorbing screens and on scattering by dielectric discs have been formulated and are being verified experimentally. Scale model studies of diffraction and scattering by various shapes, including knife-edges, cones and wedge-shaped objects are being carried out.

The diffraction and scattering of plane waves by conducting toroidal rings is being studied. The properties of a dielectric sphere, for use as a wide-angle scanning lens are being studied. A theoretical and experimental investigation is being made of the fields existing near sharp corners of imperfectly conducting bodies.

Various methods for solving wave equations in boundary-value problems are being studied. A method is being developed for obtaining solutions of the scalar wave equation in certain coordinate systems which are non-separable. The propagation of waves in non-uniform wave-guides and horns, and in non-homogeneous media are being studied. Integral equations of the Wiener-Hopf type for finite intervals are being investigated, with a view to applying them to diffraction problems of ribbon gratings.

The theory of multi-mode cavities as applied to the design of microwave filters is receiving some attention. The properties

of symmetrical waveguide junctions containing ferrites are being obtained. Propagation in waveguides is being analyzed by separating the wave into elementary components and considering the effect of a discontinuity on each component.

In circuit theory, some attention is being given to the use of signal flow graphs in network analysis and synthesis.

Methods for the analysis and synthesis of multivariable feedback control systems are being studied. This problem is closely related to multipole network theory.

Transfer function models for human operators acting as data transmitting links are also being studied.

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France

N° 212. — Report of the National Committee to Commission VI

(*Translation*)

The field of Commission VI is too extended for allowing an homogeneous coverage by the contributions of one country only. As a result such contributions may appear ill-assorted, and impossible to summarize completely in a short report.

However, the list of contributions that should be discussed at the General Assembly is reproduced below.

Sub-Commission VI.1

Study of the concept of instantaneous power spectrum (A. Blanc-Lapierre and B. Picinbono). — Various functions may be taken as a basis for defining an instantaneous frequency. The relative character of these definitions is emphasised.

Study of the inverse random function's spectrum, and its applications (R. Fortet). — The title is sufficiently clear. This study is concerned with the random function $Z = I/X$ where X is a random function defined by its statistical properties.

Following a proposal of Prof. B. van der Pol, the work of Colonel Lochard *On the determination of the type of emissions producing a minimum of interferences* should be discussed at the General Assembly.

Binary channels (M. Loeb). — Theoretical study and method proposed for studying complete telecommunication systems.

Instantaneous spectrum and signal analysis (M. Deman). — Signal decomposition in elementary time-frequency signals, whose basic properties are explained.

SUB-COMMISSION VI.2

Topological method applied to electronics (M. SIDERIADES). — Study, after Poincaré's method, of non linear first order differential equations describing the behavior of an electronic network.

SUB-COMMISSION VI.3

Two contributions, that should be listed in the rubrics of theoretical electromagnetics, are concerned with *Babinet's theorem and the concept of infinitely thin and infinitely conducting screen* (M. Poincelot).

Transition from T_{01} *rectangular to* T_{01} *circular* (M. MARIE). — The principle and operation of these transitions is based on symmetry properties of waves.

Lenses focalizing a circularly polarized wave in a given mode (M. MARIE). — Application of anisotropic propagation in a stratified dielectric medium. *Non reciprocal filters* (M. Marie). Application of the gyromagnetic effect.

* * *

The study program in the interval between the General Assembly in Boulder and the following General Assembly should insist on the following items :

Concerning commutation circuits, it may be advantageous to undertake at greater length theoretical studies on the topological conditions of these circuits and to improve the study of Boolean algebra applied to commutation circuits, bearing in mind the strict utilitarian character that these studies must finally present. Great difficulties may probably occur principally concerning Boolean algebra. The same may happen for commutation circuits topology, although it is been difficult to foresee them because the study of this topology is not very advanced. No doubt that all commutations problems will be simplified if a practical conclusion is reached in these difficult studies.

In addition, it is important to continue the study of random function's spectra. This study, already advanced in the linear cases, must be deepened in the non linear cases, particulary the noise in frequency modulation.

Germany

N° 195. — Report of the National Committee to Commission VI

In Germany the scientific circles studying the problems proposed by U.R.S.I. Commission VI are to a great extent connexed to each other through the medium of the « Nachrichtentechnische Gesellschaft » (NTG), an affiliate of the « Verband deutscher Elektrotechniker » (VDE). A close cooperation exists between the Professional Groups on « Information and System Theory », « Linear and Non-linear Networks », « Microwave Engineering », and « Antennas » of said NTG and the German National Committee of U.R.S.I. Commission VI. This close contact is made possible by practically all German Commission VI members being as well members of the NTG. Several meetings of NTG groups took place dealing with subjects which are of interest to U.R.S.I. Commission VI, inter alia, on « Noise » (München, April 1955), on « Network Synthesis » (Stuttgart, April 1956), and on « Contributions to the Theory of Signals » (Frankfurt (Main), September 1956). At these meetings papers were read and discussions held on the progress made in these fields.

In the following, research works carried out in Germany on subjects related to study projects of the U.R.S.I. Commission VI are surveyed in the light of the relevant publications for the period 1954-1956. In this survey the results are listed separately for each of the three Sub-Commissions.

I. — Communication and Information Theory

A. *Information Theory as a Means of Speech Analysis.* — The frequency of letters, letter groups and syllables of written German texts was the base for determining their entropy, using a limiting process. Values of 1.6 bits/letter or 1.3 bits/letter, when regarding word spaces, were found. These results show a good agreement with those given by Shannon for printed English. The transmission rate of information and the entropy of spoken texts were estimated too. Regarding pitch modulation, sound volume range and timbre, values between 24 and 54 bits/sec for transmission rate and 4.0 and 2.2 bits/letter for the total entropy were found. These values are widely dependent on speech velocity (1). By statistical methods, i. e. investigating the statistical distribution

of sounds to syllables, of syllables to words etc. in 11 European and extra-European languages, a mathematical law for word formation was developed. As another result of these studies it was found that every language and every author has certain specific characteristics which can be determined by investigation of the statistical distribution (2).

Another two papers deal with the information content of noisy sounds (3) and the determination of the redundant part in the common uncoded language (4). In (3) was shown that the logatom intelligibility does not increase very much when extending the upper limit of the voice-frequency band to be transmitted beyond 4.5 kc/s. The part of the voice-frequency band exceeding 4.5 kc/s which is exclusively occupied by the noisy sound spectra has therefore a redundant character with respect to intelligibility. Noisy sounds can even be distinguished as such, if only small parts of their continuous spectra going up to 15 kc/s are transmitted.

Visible speech diagrams have shown that the redundant part takes about half of the time needed for the transmission of a spoken text. Pauses between individual words and speech sounds must of course be excepted. It should therefore be possible to find a suitable method for reducing the bandwidth of a speech channel to half of its former amount (4).

Experiments with the aim to find telegraphic methods for the transmission of speech sounds in order to reduce channel capacity required for speech transmission showed that the composition of intelligible language of sound elements is impossible. A successful experiment to build up words from groups of sounds synthetically proved that the transmission of sound transitions is essential for the syllable intelligibility (5).

To improve the signal-to-noise ratio of speech transmission a system using an amplitude-clipping process was designed. The voice-frequency band is divided up into partial spectra, so that after distortion and amplitude-clipping the perturbing non linear distortion products are suppressed. A new control technique for combining the partial spectra at the receiver was developed so that the output spectrum approximately corresponds with the input spectrum (6).

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2. W. Fucks. — Die mathematischen Gesetze der Bildung von Sprachelementen aus ihren Bestandteilen, Theorie der Wortbildung aus Silben und der Silbenbildung aus Lauten, *Nachrichtentechn. Fachber.*, Band 3 (1956), 7-21.

3. F. Enkel. — Ueber den Informationsgehalt der Geräuschlaute. *Nachrichtentech. Z.*, **9** (1956), 493-498.

4. W. Endres. — Ueber die Grösse des « weitschweifigen » Anteils in der Sprache und seine Bedeutung für den Fernsprechweitverkehr. *Fernmeldetech. Z.*, **8** (1955), 89-93.

5. K. Küpfmüller, O. Warns. — Sprachsynthese aus Lauten, *Nachrichtentechn. Fachber.*, Band 3, 28-31.

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B. — Further activity related to the domain of Information Theory may be summarized in the following list of references.

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13. E. Henze. — Untersuchung einer speziellen Transformation des Fernschreib-Alphabets als Transformation von Vektoren. *Arch. elekt. Uebertragung*, **9** (1955), 528-532.

14. K. Radius. — Mehrfachübertragung durch Amplitudenvielfach. *Nachrichtentech. Z.*, **9** (1956), 403-407.

II. — Circuit Theory

The work carried out in this field refers to the classification of basic system elements and the use of new circuit elements, to methods for the calculation of active and passive networks, especially to the realization of filters with given properties (network synthesis), as well as to investigations into the transient behaviour of networks. The most important publications are listed below.

1. F. A. Fischer. — Transformatoren und Gyratoren in Mechanik und Elektrik. *Arch. elektr. Uebertragung*, **8** (1954), 15-19.

2. F. A. Fischer. — Zur Definition des idealen Transformators und des idealen Gyrators durch ihre Scheinwiderstandsumbildenden Eigen schaften. *Fernmeldetech. Z.*, **8** (1955), 309-311.

3. Willi Doebke. — Bemerkungen zum Gyrator-Problem. *Arch. elekt. Uebertragung*, **8** (1954), 197-200.

4. W. Nonnenmacher, F. Schreiber. — Der Zweidrahtverstärker als Gyrator und als Vierpol zur Herstellung ungewöhnlicher Scheinwiderstände. *Frequenz*, **8** (1954).

5. H. Beneking. — Aktive Vierpole in Zwischenbasisschaltung. *Arch. elekt. Uebertragung*, **9** (1955), 519-527.

6. W. Bader. — Rationale Gegenkopplungs- und Entzerrungsschaltungen oder Folgeregler mit vorgeschriebenen Eigenschaften. *Arch. elekt. Uebertragung*, **8** (1954), 285-296.

7. H. Haller. — Beiträge zum Problem der Gegenkopplung. *Frequenz*, **9** (1955), 164-172, 188-199.

8. H. Pecher. — Die Leitwertmatrix passiver und aktiver Netzwerke. *Arch. elekt. Uebertragung*, **10** (1956), 494-498.

9. H. Ebel. — Negative Widerstände mit Transistoren in der Netzwerksynthese. *Nachrichtech. Z.*, **9** (1956), 513-518.

10. V. Fetzer. — Explizite Berechnungsformen für Filterschaltungen mit allgemeinen Parametern. *Arch. elekt. Uebertragung*, **8** (1954), 31-46.

11. B. Betzenhammer, E. Henze. — Theoretische Untersuchungen über dreikreisige Bandfilter vom Tschebyscheffschen Typ. *Arch. elekt. Uebertragung*, **8** (1954), 545-552.

12. H. Matthes. — Zur Ebnung der Verlustdämpfung von Grundkettenfiltern. *Frequenz*, **8** (1954), 17-28.

13. H. H. Voss. — Realisierbare Tiefpässe und Bandpässe minimaler Phase mit geebneter Laufzeit und aperiodischem Einschwingverhalten. *Frequenz*, **8** (1954), 97-102.

14. G. Bosse. — Bandpassschaltungen mit minimaler Spulenzahl. *Frequenz*, **8** (1954), 186-192, 221-225.

15. W. Krägeloh. — Vierpole, deren Uebertragungsfaktor Nullstellen mit kleinem Realteil aufweist. *Frequenz*, **8** (1954), 249-256.

16. E. Willwacher. — Filter für Mikrowellen. *Fernmeldetech. Z.*, **7** (1954), 694-704.

17. E. Henze. — Bandfilter vom Tschebyscheffschen Typ mit beliebig vielen Kreisen. *Arch. elekt. Uebertragung*, **9** (1955), 131-139.

18. H. Kaufmann. — Zur Bestimmung von Frequenz-Charakteristik und Phasenmass eines Netzwerks bei beliebig vorgegebener Dämpfungkurve. *Arch. elekt. Uebertragung*, **9** (1955), 192-198.

19. J. PETERS. — Gleichzeitige Approximation der Amplitude und der Laufzeit eines idealen Tiefpasses mit Hilfe der Strömungs-Analogie. *Arch. elekt. Uebertragung*, **9** (1955), 453-459.

20. F. L. BAUER. — Die Betriebs-Kettenmatrix von Vierpolen. *Arch. elekt. Uebertragung*, **9** (1955), 559-560.

21. E. HENZE. — Bandbreiten verschiedener Filterschaltungen und effektive Rauschbandbreiten nach C.C.I.R.-Empfehlungen. *Fernmeldetech. Z.*, **8** (1955), 512-515.

22. V. FETZER. — Vergleich von Filtern nach der Wellenparametertheorie mit den Filtern der Betriebsparametertheorie und die neuzeitlichen Methoden der Filterberechnung. *Arch. elekt. Uebertragung*, **10** (1956), 225-240.

23. J. DÖRR. — Die fundamentalen Uebertragungsfunktionen des Tiefpasses, ihre Eigenschaften und ihr Realisierungsproblem. *Nachrichtentech. Z.*, **9** (1956), 356-364.

24. E. HENZE. — Abriss einer verallgemeinerten Filtertheorie. *Arch. elekt. Uebertragung*, **10** (1956), 541-551.

25. G. MAHLER. — Gestaffelte Tiefpassverstärker mit hoher Grenzfrequenz. *Frequenz*, **10** (1956), 296-303, 319-328.

26. V. FETZER. — Das Uebertragungsmass von Netzwerken mit vorgeschriebenem Einschwingvorgang. *Nachrichtentech. Z.*, **9** (1956), 462-468.

27. W. POSCHENRIEDER. — Steile Quarzfilter grosser Bandbreite in Abzweigschaltung. *Nachrichtentech. Z.*, **9** (1956), 561-565.

28. R. UNBEHAUEN. — Neuartige Verwirklichung von Zweipolfunktionen durch kanonische oder durch kopplungsfreie Schaltungen. *Nachrichtentech. Z.*, **9** (1956), 565-572.

29. F. BAUHUBER. — Praktische Verfahren zur Aufstellung des Hurwitz-Polynoms in der Filtersynthese. *Nachrichtentech. Z.*, **9** (1956), 573-580.

30. V. FETZER. — Der Zusammenhang zwischen Zeitfunktion und Frequenzfunktion nebst praktischen Beispielen zur Bestimmung des Einschwingvorganges in linearen Uebertragungssystemen. *Arch. elekt. Uebertragung*, **8** (1954), 163-172.

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32. V. FETZER. — Die praktsiche Berechnung des Einschwingvorganges bei beliebiger Dämpfungs- und Phasenverzerrung. *Arch. elekt. Uebertragung*, **8** (1954), 467-477.

33. H. KADEN, F. BATH. — Ueber die Verzerrungen von Fernsehsignalen infolge von Dämpfungs- und Phasenverzerrungen der Uebertragungleitung. *Arch. elekt. Uebertragung*, **8** (1954), 55-68.

34. H. H. NISSEN, W. HÄNDLER. — Das Einschwingverhalten von Filtern mit charakteristischem Amplitudengang. *Arch. elekt. Uebertragung*, **9** (1955), 74-80.

35. E. Henze. — Einschwingvorgänge bei Amplituden- und Frequenzmodulation an einigen speziellen passiven Netzwerken. *Arch. elekt. Uebertragung*, **9** (1955), 326-338.

36. F. Baur. — Einschwingverhalten von Bandfiltern. *Frequenz*, **9** (1955), 141-146.

37. H. Marko. — Die Reziprozität von Zeit und Frequenz in der Nachrichtentechnik. *Nachrichtentech. Z.*, **9** (1956), 222-228, 266-271.

38. H. Wahl. — Ortskurven einiger elementarer transzendenter Funktionen. *Frequenz*, **8** (1954), 346-351.

39. W. Krägeloh. — Ermittlung der Zweipolfunktion, deren komplexe Werte in einem Teilbereich reeller Frequenzen vorgeschrieben sind. *Arch. elekt. Uebertragung*, **9** (1955), 375-380, 419-431, 479-483.

40. R. Hofmann, W. Walcher. — Ueber ein einfaches Verfahren zur numerischen Berechnung von Zeitfunktionen bei gegebenen gebrochenen rationalen Funktionen im Unterbereich. *Arch. elekt. Uebertragung*, **9** (1955), 475-478.

41. E. Henze. — Beiträge zur Theorie der Nichtlinearitäten. *Arch. elekt. Uebertragung*, **10** (1956), 326-338.

III. — Research in Electromagnetic Waves

A. *Diffraction Theory.* — The diffraction of electromagnetic waves by a cylinder and by a sphere with infinite conductivity is treated for intermediate wavelengths (1, 2, 3), for which the conventional methods (Mies or Kirchhoff's Theory) do not work, either for reasons of slow convergence or of failure of the approximation. The concept of creeping waves is introduced which propagate along the shadow side of the surface of the diffracting obstacle and interfere there with the geometrically reflected wave. This concept is developed from integral equation formulations of diffraction problems as well as by Watson transform methods and gives a very instructive physical picture of the situation with results in agreement with experiments.

The problem of diffraction of electromagnetic waves by infinitely thin and perfectly conducting screens of arbitrary shape is formulated in terms of two integral equations for the Fourier amplitudes of a Hertz and a FitzGerald vector (4). Two methods of approximate solution are indicated of which one starts with Kirchhoff's integral as first approximation.

B. *Hollow Wave guides.* — The limiting frequency and the wave resistance of ridge waveguides are examined for arbitrary cross

section (5). Both quantities can be greatly varied by suitable shape of the cross section.

The propagation of waves in wave guides with circular cross section is examined for all modes near the limiting frequency in case of a finite surface conductivity (6). The results indicate a new method of frequency stabilization of emitters. The transmission properties of a hollow cable can be improved by inserting a concentric dielectric tube (7). By suitable choise of the dimensions the minimum damping and one extremal value of the group velocity occur at the same frequency. The conditions for broadband cables are discussed. — The excitation and propagation of E_{on}-waves is treated in the case that the electromagnetic energy is fed into and extrated from the circular wave guide by coaxial lines (8). The mathematical treatment is in terms of transducer concepts. — The electromagnetic field near the transition from a coaxial line to a hollow wave guide is evaluated by the method of least squares (9). For rectangular wave guides with H_{01}-waves, a suitable analogy to the wave resistance of transmission lines is given (10).

The theory of radial propagation of electromagnetic waves between two conducting planes is developed (11). The results are used for the determination of the dynamical capacity of a capacitor. The radiation field of oscillating electric and magnetic dipoles gives a good approximation for the propagation of electromagnetic waves between the surface of the earth and the ionosphere in the case of long waves ($\lambda > 3$ km). For some dipole orientations resonance phenomena occur if the height of the ionosphere is an integer multiple of a half wave length.

Helix wave guides can be given the property of a band pass filter by introducing inhomogeneities, for instance periodical variations in slope. The reflexion and transmission coefficient of a wave guide helix, whose (constant) slope has a discontinuity, are evaluated (12).

C. *Surface wave guides.* — The theory of the Harms-Goubau line is given (13) for meter wave lengths (thick dielectric coating). Also the case of several dielectric layers is considered including a dielectric screening tube and the increase of damping by a deposited layer of ice is studied.

The mutual interaction (field distribution and exchange of energy) of parallel surface wave guides is treated (14).

D. *Dielectric wave guides.* — In order to investigate the transmission properties of a dielectric tubular wave guide, the field excited by a dipole is determined (15). The propagation mechanism of the natural waves is explained by repeated total reflexion. The HE_{11}-mode has the most favorable properties and can be used for economic transmission of communication in the cm-domain.

The quantities of interest, the phase constant, damping and the range of the field are evaluated for the HE_{11}-mode, especially in the case of small dielectric constant. The limiting case of the dielectric rod is included and the maximal attainable field concentration is determined (16). Theoretical results are summarized and numerical values are given in (17).

E. *Wave fields.* — One paper (18) is concerned with the propagation of electromagnetic waves in a pyramidal horn and gives results for the near and the far field and the damping in dependence of the mode and the angular aperture of the horn. With a view to the attenuation of metal plate lenses to the horn radiator, the reflexion and transmission coefficient of an array of metal plates for an incident plane wave are determined (19). Also the effect of insertion of dielectric plates on both sides of the metal plates is studied.

Two papers (20, 21) are concerned with the measurement of the transmission of electromagnetic waves through inhomogeneous layers with emphasis on the reflectance of loss free layers and of layers with loss. The principal methods for the construction of reflexion free absorbers (acoustical and electromagnetic) are discussed (22) and broad banded resonance absorbers are described (23) which consist of a regular array of absorbing electrical dipoles located at a quarter wave length from a metal wall. — Two multidimensional iterative networks, which have been built in Darmstadt (24), are used as models for wave fields of different kinds. As an example the near field of Pylon antennas is treated. The behavior of a perfectly conducting torus under the influence of high frequency currents and of magnetic fields is studied and explicit results are given for most cases (25).

F. *Transmission Theory.* — Slight random local variations of the wave resistance in transmission lines are studied and a relation between its correlation function and the spectrum of the mean square deviation of the input resistance is established (26). The synthesis of transducers with prescribed properties consisting of inhomogeneous transmission lines is made possible by a distinct reformulation of the transmission line properties (27, 28). An example concerns problems of broad banded resistance transformation and compensation. Two twin conductors with electromagnetic coupling over a certain length can be considered as an 8-terminal network, which possesses several interesting and useful properties, for instance that of a directional coupler (29). Mathematical results and indications for applications and dimensioning are given.

G. *Antenna Theory.* — Although familiar methods of antenna calculation apply to special geometrical shapes of antennas, some general statements can be made regarding radiation field and antenna impedance. Thus a direct relation between antenna inductance and overall frequency response of the radiation resistance can be derived from the analytical character of the impedance function. The finiteness of the reactance concentrated in the antenna is proved, a long wave dipole of maximum damping is calculated. Moreover, a conversion can be made from the limiting case of a reactance of an antenna enclosed in a cavity to the impedance of a radiating antenna. Finally, it can be shown for which classes of given fields it is subsequently possible to find conductor configurations satisfying the boundary conditions, in analogy to a known method of potential-theory (30).

In the field of broadband antennas theoretical and practical investigations have primarily been carried out by the « Institut für Hochfrequenztechnik » of the « Technische Hochschule », München (Prof. Dr. Meinke). Object of these investigations was the determination of the transition region between coaxial transmission line and antenna as well as the antenna shape in such a way as to obtain optimum broadband characteristics. The papers of the synthesis of lossless quadripoles from lines with varying characteristic impedances (27, 28) are to be considered as the first step towards this end. This subject has been extended

to lines with losses so as to approach the antenna problem. In addition, investigations have been made with a view to improve the broadband properties of antennas by impedance quadripoles by which the bandwidth can be more than doubled compared with the result obtained from a reactance circuit (31). An improvement of the effective area of a cylindrical parabolic reflector with horn-shaped aperture could be achieved when correcting the phase front by insertion of a phase lagging metal sheet in the central plane of the horn (32).

In the case of plane aerials with continuous illumination the effect of the aperture shape on the radiation pattern has been investigated both theoretically and experimentally. It is far easier to reduce the sidelobes by choosing an appropriate cross section of the aperture (rhombus, $\cos^2$, etc.) than by a corresponding illumination using rectangular or circular aperture (33).

As regards a line-source antenna with continuous distribution the optimum distribution function in form of a Fourier series was investigated for broadside and end-fire arrays. These investigations showed among others that in addition to an amplitude distribution decreasing towards both ends, a phase distribution decreasing more than linearly towards the ends is advantageous for the end-fire array (34). From the correlation between the distribution of intensity on radiating systems and their directional radiation patterns it was shown how to determine the distribution of the disturbing intensity from an infinite family of directional patterns in case of scattering media with geometrically distributed disturbances of the dielectric constant (35). The phase center was calculated for a wave emitted from a plane aerial using Kirchhoff's formula (36).

A flat sheet antenna with a radiation pattern in the form of a cone-shaped shell was developed on the basis of the radiation from wave guides with leaky walls (37).

Formulas and curves were derived for the radiation resistance and gain of rhombic antennas as a function of the antenna data, these formulas and curves taking approximately into account the attenuation caused by the radiation (38).

Investigations into ground antennas showed by computation and measuring technique that with regard to the signal-to-noise ratio these antennas do not offer any advantage over the conventional antennas (39).

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Italy

N° 163. — Report of the National Committee to Commission VI

Radio waves

Several studies have been carried out on waveforms and on the relative methods of analysis.

As far as electromagnetic theory is concerned, four main lines of research can be pointed out :

1) Theoretical and experimental studies on properties of the field equations ;

2) Theoretical studies on microwave lenses ;

3) Works on antennas and on their imput characteristics ;

4) Studies relative to propagation in empty guides or in guides filled with magnetized ferrite.

With respect to N.4 it should be mentioned the increasing interest in this country for theoretical and experimental studies on devices employing ferrites. Works on ferrite insulators and analysis of the mode spectrum in guides filled with gyromagnetic media are in publication.

Circuits

With respect to the circuit theory, several lines of scientific interest can be pointed out :

1) The difficulties encountered in the circuit analysis by means of Fourier and Laplace integrals have been analyzed and some original contribution given.

2) Several studies have been carried out on the synthesis of electrical networks. Among these, studies should be mentioned aiming at the identification of new properties of the

synthesis problem. Considerable attention has been given to the analysis and synthesis of filters, particularly with respect to practical design criteria.

3) In the field of feedback control systems some studies have been carried out on the analysis of various circuits, and in general on the feedback active networks.

4) Should also be mentioned contributions to the study of systems with variable parameters and of non linear systems.

Both on the fields of radio waves and circuits it should be mentioned several systematic analysis of the most up to date subjects. In this respect several books on electromagnetic waves, on operational calculus and on network synthesis should be pointed out. Not all these works have been included in the bibliography.

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Japan

N° 202. — Report of the National Committee to Commission VI

by Kiyoshi MORITA, *Chairman*

Following « Technical Resolutions » and « Proposals for Future Work », described in the Proceedings of the XIth General Assembly Volume X, Part 6, scientific works have been done much in Japan. Some of them were already refered in the *Information Bulletin No* 96. The papers underlying concern with the subjects dealt with by the three sub-divisions of Commission VI. Naturally the original papers are written in Japanese language, however there is attached for each paper, except those which are published in Annual Conventions, an abreviated summary in English which will help somewhat.

The joint meetings of Commission IV and VI to solve the problem of interrelationship between atmospheric noise and design of circuits were held several times, and we are getting close to reveal the nature of atmospheric noise but not yet we have concrete results.

I. — INFORMATION THEORY

As to researches on the fundamental ideas, the transmission rate in a Markovian noisy discrete channel was defined, with a discussion on calculation of its channel capacity (1). The capacity of the resultant channel consisting of cascade connection of the same noisy channels was calculated (2). Also, some improvement on the Muller's error-detecting codes was done (3).

Certain theorems on the sampling of a complex wave form of signal were obtained (4). Studies on problems relating to the correlation functions had been active (5, 8).

As to applications, the optical systems had been actively studied from a stand point of the information theory (9, 11) and a new interesting principle of the transmission of television signals depending on their statistics was proposed (12).

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II*a*. — LINEAR NETWORK THEORIES

As to the theory on two-terminal networks, a work on a relation between a two-terminal network without use of mutual inductances and equivalent circuits which may be derived by a transformation on the Brune's network, using all-pass networks, has been done. As to the filter theory, sufficient conditions that a band-pass ladder network is realized without negative elements, and that its serial arms (or parallel arms) are realized only with condensers, that is, the number of coils in the whole networks is to be minimized, are derived. And then a method to design such a network with a minimum number of coils by a certain kind of frequency transformation is shown. Also an easier method to find approximate factors in a factorization of polynomials encountered in the filter design is devised.

II*b*. — Nonlinear circuits

In the field of theoretical research of nonlinear circuits, how to express the nonlinear characteristics of elements mathematically depends upon the type of phenomena of objects, and is important to simplify the analysis. Many considerations about this have been reported, and someone has tried to discuss the dynamic characteristics of magnetic hysteresis by transforming it into the boundary value problem of partial differential equations. (1, 2).

As the analytical method of nonlinear circuits, especially the graphical method has been developped, and energy function method and Jocobson's phase plane-δ method have been extended. The energy function method is to apply the relation between the potential energy and kinetic energy in dynamic system into the electrical circuits (3, 4, 5).

Many analyses have been also tried about the phenomena occurring in the nonlinear circuits (6, 7, 8, 9) moreover, about the phenomena occurring from the combination of electrical and other physical systems, for example dynamic system (10, 11, 12).

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7. Tomoharu Tanaka. — The resonance characteristics of the nonlinear circuits. *Convention of I.E.C.E. Jap.*, Nov. (1956).
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III. — Waves and diffraction

Research on microwave passive relay using a flat reflector was made by means of geometrical optics and many experimental and practical results of it were published.

The defocussing effects of a paraboloidal reflector were discussed theoretically, (1) and new primary exciters for paraboloid utilizing the circularly polarized waves were contrived in order to get a wide band matching.

Modified folded dipole antennas were contrived to obtain a wide band frequency characteristics (2, 3).

The characteristic of « Balun » used for a matching device between co-axial and parallel line feeder was computed rigorously by aid of the multitransmission line theory (4).

Electromagnetic field in a cavity were rigorously worked out by means of an expansion of orthonormal functions, and it was shown that irrotational function should be considered in expressing the field (5). Propagation constant in a waveguide with wall losses and phase distortion were studied more precisely by applying the variational methods or the integral equations (6, 7).

Diffraction by an infinite strip plate or slot in an infinite plate were worked out with applying the modification of Schwarzschild method (8), and moreover the multiple diffraction by spherical mountains were carried out (9).

The propagation of the over-horizon and of acrossing two boundaries of discontinuity were treated experimentally and theoretically (10).

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Netherlands

Nº 233. — Report of the National Committee to Commission VI (1954-1957)

Since the last General Assembly of U.R.S.I. held at the Hague in 1954, most activity in the Netherlands in the domain of Commission VI centred around the subjects of Communication and Information Theory (Sub-Commission VI.1) and of Circuit Theory (Sub-Commission VI.2). Only few papers have been published that belong to the domain of Electromagnetic Theory (Sub-Commission VI.3).

Sub-Commission VI.1

Communication and Information Theory

Du Mosch (1) and Van Soest (2) have contributed to the study of the continuous process. Schouten (3) contributed to the philo-

sophical aspect of information at the 3rd London Symposium. An important step towards the application of information theory to practical communication systems was made by Knudtzon (4) in his doctor's dissertation taken at Delft Technical University. Six (5) has reported on a new type T.O.R. system, while Cohen and Jung (6) discussed the merits of the detection system used for this special purpose. In addition, Van der Pol (7) has treated the problem of diversity reception, a problem strongly related to information theory. Studies of the human eye, of importance for the application of information theory to television, were reported upon by De Lange (8) and Van der Tweel (9). Finally, Stumpers (10) has added two supplements to his list of bibliographical material published in the Transactions of the IRE (PGIT).

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9. L. Van der Tweel. — The reaction of the human pupil on variations of illumination (in Dutch). *Thesis Amsterdam* (1956).
10. F. L. H. M. Stumpers. — Supplement to a Bibliography of Information Theory : Communication Theory-Cybernetics. *Trans. I.R.E. (P.G.I.T.)*, Sept. 1955. Second supplement, *Philips Research Laboratories*, Jan. 1957. (Will also be published in *Trans. I.R.E.*).

Sub-Commission VI.2. — Circuit Theory

Under the supervision of Prof. Tellegen, two doctor's dissertations in the field of this Sub-Commission have been prepared. In the

first of them, by Bordewijk (1), the concept of inter-reciprocity has been introduced as an extension of that of reciprocity. Inter-reciprocity applies both to reciprocal and to non-reciprocal structures. In addition, a topological network operation, called transposition, has been devised such that a network and its transpose become inter-reciprocal. Transposition is applied in a number of direct calculations as well as in more general cases concerned with transmission and noise properties of gyrator, triode and transistor networks. The second dissertation, by Neeteson (2), is a monograph on the operation of the bistable multivibrator circuit. Triggering and transient phenomena have been analyzed in detail, so as to come to practical rules enabling the design of these circuits. Measurements on actual circuits agree very well with results predicted by theory. Tellegen (3) has reported on his search for a complete set of non-linear circuit elements. An alternative approach to the gyrator has been published by the same author (4). Finally, a paper by Thirup (5) deals with the design of low-pass amplifiers for fast transients.

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2. P. A. Neeteson. — Analysis of bistable multivibrator operation. *Thesis Delft* (1956).
3. B. D. H. Tellegen. — La recherche poûr une série complète d'éléments de circuit idéaux non-linéaires. *Rend. Sem. mat. fis. Milano* (1953-1954), 25, 134-144 (1956).
4. B. D. H. Tellegen. — The gyrator, an electric network element. *Philips tech. Rev.*, 18, 120-124 (1956-57).
5. G. Thirup. — Design of low-pass amplifiers for fast transients. *Philips Res. Rep.*, 10, 216-230 (1955).

Sub-Commission VI.3. — Electromagnetic Theory

Almost no activity has been displayed by Dutch people in the field of antennas, waveguides, diffraction, etc. Except the first paper cited below, all papers that deserve mention here are due to non-Dutch scientists.

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2. A. Nisbet. — Source representations for Debye's electromagnetic potentials. *Physica*, 21, 799-802 (1955).

3. J. R. Wait. — Radiation from an electric dipole in the presence of a corrugated cylinder. *Appl. sci. Res.*, B 6, 117-123 (1956).

4. R. G. Kouyoumjian. — The backscattering from a circular loop. *Appl. sci. Res.*, B 6, 165-179 (1956).

5. V. J. Vanhuyse. — On the proper frequencies of terminated corrugated waveguides. *Physica*, 269-280 (1955).

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Poland

N° 207. — Report of the National Committee

Sub-Commission VI.1. — Information Theory

The main effort was devoted to the study of the basic concepts of the information theory, especially to the study of relations between the information theory and statistical methods. An investigation was made into the problem of applying entropy as a characteristic of continuous systems that are not coded. In connection with it the relation between Wiener's and Shannon's methods was discussed (1.1).

The method of orthogonal expansions was applied to give a uniform treatment of the problem of communication in the presence of non-stationary gaussian noise if the transmitted signals are discrete or are the realizations of non-stationary process. Various statistical criteria were considered (1, 2).

A certain extension of Wiener's method was introduced in the papers (2.14), (2.15). They are primarily devoted to the circuit theory.

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Sub-Commission VI.2. — Circuit Theory

To describe the recent research work let us specify the following fields :

A. Analysis of linear systems,

B. Design and synthesis of linear systems,

C. Analysis of non-linear systems.

A. — *Analysis of Linear Systems*

Much consideration has been given to the analysis of phenomena occurring in concrete linear systems (2.27, 2.30, 2.21, 2.31, 2.9, 2.29, 2.11). Although the methods applied do not differ much from the well-known ones, some results of practical interest have been obtained.

B. — *Synthesis and Design of Linear Systems*

1. Different problems of the synthesis RC and RLC circuits have been considered : forming the voltage impulses of a desired form (2.10) ; the case of bridge networks with transcendental transfer functions (2.19) ; the realization of the real transfer characteristic given in graphical form, and uniform approximation of the given functions of time or frequency (2.20).

2. In the domain of amplifier design the following have been considered : appropriate distribution of the poles in multistage impulse and resonance amplifiers (2.1) ; the three circuit resonance amplifier with Tchebyshev characteristics (2.28, 2.22) ; and approximations of time characteristics which minimize distortion and time of growth (2.12, 2.16).

3. A study was made of the criteria of dynamic quality and noise suppression for linear systems (2.13, 2.14, 2.15, 2.17). An isoperimetric criterion was introduced for the minimum square distortion of a signal with noise of limited power (2.13).

4. There were considered the properties of a criterion of quality of filters taking simultaneously into account the deviation of the desired frequency characteristics in the transmission band and the slope of the characteristics in the rejection band.

C. — *Analysis of non-linear systems*

The work in the field of analysis of non-linear generators was initiated in Poland before the war by Prof. J. Groszkowski who introduced the principle of equilibrium of the harmonics. The book (2.8) published after the war constitutes a monograph sum-

ming up the results obtained. Recently a series of further papers on the problems of non-linear generation (2.2, 2.3, 2.4, 2.5, 2.6, 2.7) has been published.

An interesting generalization of the principle of equilibrium of the imaginary powers is given in the paper (2.2). The paper (2.5) contains a complete analysis of the frequency stability of a Clapp oscillator if linear and non-linear effects are considered. The theoretical analysis has been verified experimentally (2.27). The influence of the grid current harmonics on generator frequency is analysed by applying theory of equilibrium of imaginary powers in the paper (2.24, 2.25).

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2.16. R. KULIKOWSKI. — The Design of Pulse Systems Based on the Method of Moments. *Arch. Elektrot.*, 1, 1956.

2.17. R. KULIKOWSKI, A. RYBARSKI. — Criterion for Root Square Distortion at Limited Noise Power. *Arch. Elektrot.*, 2, 1956.

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2.24. L. LUKASZEWICZ. — The Influence of Grid Current upon Valve Oscillator Frequency. *Bull. Acad. Polon. Sci.*, IV, 4, 1954.

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2.26. J. OSIOWSKI. — The Analysis of the Voltage Phenomena in the Anode Circuit of a Class C Resonance Amplifier. *Arch. Elektrot.*, p. 521, 1955.

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2.29. A. SMOLINSKI. — Operation of a Valve in a Grounded-grid Circuit. *Arch. Elektrot.*, p. 621, 1956.

2.30. S. SLAWINSKI. — The Influence of the Input Frequency on the Stiffness and Loading Capacity of a Synchrotransmission System. *Arch. Elektrot.*, p. 547, 1955.

2.31. F. WISNIEWSKI. — The Analysis of the Superregenerative Circuit with Quenching Frequency Modulation. *Arch. Elektrot.*, p. 263, 1956.

SUB-COMMISSION VI.3. — ELECTROMAGNETIC THEORY

Sub-Commission VI.3 has suggested four topics which it considers specially important. The state of research in these fields is as follows :

Topic 1. « Study of theory of broad band antennas including the transition region in their design ».

No research work has been carried out.

Topic 2. « Further study of the transitions from Maxwell's equations to the limiting cases of the geometrical optics on the one hand and circuit theory on the other ».

Two methods of approximation of the solutions of Helmholtz equation were investigated (3.1, 3.2). The aim of the first is to improve the accuracy of the approximation as given by geometrical optics. This method introduces an equivalent index of refraction

$$n = \sqrt{1 + \frac{\Delta A_0}{k^2 A_0}}$$

where A_0 is the amplitude determined by geometrical optics.

The second method analyses the equations given by the W. K. B. procedure. In connection with it the extension of the eikonal equation into the complex case was investigated (3.3). The relation between the first approximation obtained by this method and the inhomogeneous plane waves is analogous to the relation between geometrical optics and plane waves.

Topic 3. « Further study of guided waves including surface waves and the transmission through anisotropic media ».

Research on this topics was concentrated on the transients in wave guides. The exciting source was taken into account (3.6, 3.7). Recently R. Gajewski obtained approximate solutions for the case of moderate losses in the walls.

Topic 4. « The design of antennas for trans-horizon communication».

No research work has been conducted.

Besides the above listed topics the following research has been carried out.

The effect of electron beams on detuning the cavities has been analysed (3.8, 3.9). The influence of various parameters on the field amplitude in a cavity is also considered.

There were investigated differences between the properties of Kirchhoff formulae and Kottler formulae in the far zone (3.10), and the generality of analysis of the electromagnetic field by means of Hertz vectors (3.11).

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3.5. R. Gajewski. — On Transients in Wave Guides. *Bull. Acad. Polon. Sci.*, Cl. IV-III, 1, 1955.

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3.7. R. Gajewski. — *Idem*, II. *Acta Phys. Polon.*, in print.

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Sweden

N° 218. — Report of the National Committee to Commission VI

(Erik Hallén)

VI.1. — In the field of *Communication and Information Theory* work is carried out in a laboratory (Tech. lic. G. Fant under Professor T. Laurent) at the Royal Institute of Technology in Stockholm. There is also activity in the field at Chalmers Institute of Technology in Gothenburg, Professor H. Wallman. I refer to items 1-8 in the bibliography.

VI.2. — In several branches of *Circuit Theory* there is activity in different places.

At the Royal Institute of Technology, Division of Radio Technics, Professor E. Löfgren, a research group investigates applications of transistors as to their high frequency properties power transistors and for power technique application. For the future even applications on pulse technic are under consideration.

At the Research Institute of National Defence (FOA) in Stockholm work has been carried out on creating ferrite materials for polarization rotation, first for 3 cm waves, later for greater wavelengths hitherto up to 10 cm. Also ferrite material for other microwave applications are investigated. Some work has been done in developing microwave components (isolators, switches and phase changers) with the help of ferrites.

I also refer to items 9, 10, 14, 15, 16 in the bibliography by Professor Aurell and Professor Ekelöf of Chalmers Institute of Technology in Gothenburg.

VI.3. — In the field of *Antennas and Waveguides* the following activities in Sweden should be mentioned.

At the Research Institute of National Defence (FOA) aircraft antennas for several types of aircraft have been developed especially broad band omnidirectional antennas for communication and broad band omnidirectional and directional antennas for navigation in the VHF and the UHF range. Both outside and suppressed antennas have been developed.

At the Telefonaktiebolaget L. M. Ericsson, Stockholm, the broad band properties of several types of microwave antennas have been studied, such as symmetrically fed paraboloidal reflectors and horn reflector antennas.

Work on antennas is also carried out at the Royal Institute of Technology, Division of Theoretical Electrical Engineering, Stockholm, Professor E. Hallén. Beside the mathematical application of Maxwell's equations on antenna problems experimental work is done in the laboratory, especially on *reflection free antennas*. If in any antenna the usual metal radiating structure is exchanged by a body of suitably continuously varying impedance one can arrive at a radiating system in which the outgoing travelling current waves continuously decrease in amplitude and are not reflected back to the feeding region. The antenna becomes perfectly

aperiodic. It will be « infinitely broad banded » with constant radiation impedance above a certain lowest frequency. Experimental studies of such antennas have been carried out by E. Cassel. More applications for instance in construction of reflection free directional antennas are planned.

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Summary : TVR (= Television + Röntgen) designates the technique of transmitting X-ray fluoroscopic images by means of television. TVR is of value in cancer therapy, where the X-ray dose is too high to permit a doctor to remain in the treatment room in order to ensure that the X-rays pass exactly through the tumor. Anatomical considerations usually make the correct adjustment of the direction of X-rays rather difficult, especially in « rotation therapy », in which the patient lies in a fixed position on the treatment table while the X-ray tube rotates around him. (The purpose of this rotation is, of course, to distribute the damaging skin dose over as large an area as possible.)

Work on TVR has been in progress at the Division of Teletechnique of Chalmers University of Technology since September 1954, and involves cooperation with the Memorial Clinic of Sahlgrenska Hospital in Göteborg. Financial support has been granted by the Swedish Cancer Society.

A number of difficulties arise in the work on TVR, of both röntgenological

and electronic nature. One of the severe electronic problems lies in the sensitivity required in the television process. The luminance of the fluoroscopic screen achieved in fluoroscopic examination of an abdomen is about 0.01 apostilb (= 0.001 foot lamberts), which is about 10 000 times lower than the luminance level usual in television studios.

The present paper contains an analysis of signal/noise relations in television camera tubes and in the subsequent video amplifier stages at low light levels. The analysis is based on computation of the number of elementary particles — light quanta or electrons, as the case may be — per picture point and time interval; the signal/noise ratio in the various stages of the television chain are determined by direct statistical reasoning based on the number of elementary particles.

Fundamental sensitivity limitations appear which are independent of the type of cameratube — image orthicon or vidicon, for example. Other limitations are of less fundamental type. An « ideal » camera tube for such applications is discussed. The paper concludes with a description of a provisional but practically rather satisfactory solution achieved by use of an image amplifier tube.

VI-2. — *Circuit Theory*

9. C. G. Aurell (CTH). — The equivalent transmission line of a four-terminal network. Calculations with cascade connected four-terminal networks. *Ericsson Technics*, 1956, n° 2, pp. 107-145.

Summary : The concepts of image impedances, complex image attenuation, and of the equivalent transmission line for a four-terminal network are critically examined. The idea of a wavesymmetric transmission line is introduced, and for this the appropriate relationships are formulated. Its suitability as the equivalent transmission line also for non-symmetrical four-terminal networks is shown. The transmission-line analogy is developed further to include non-reciprocal four-terminal networks. The theory is applied to cascade connexion of several linear, but otherwise arbitrary, four-terminal networks.

10. C. G. Aurell (CTH). — Representation of the general linear four-terminal network and some of its properties. *Ericsson Technics*, 1955, n° 1, pp. 155-179.

Summary : Special attention is devoted to the representation of and to the properties of the non-reciprocal four-terminal network. A new method of representation is proposed. The loss or gain of such networks are dealt with under very general assumptions, and possible extreme values are derived and the conditions for their existence are discussed.

The conditions for the optimum matching of given four-terminal network are derived.

The classification of four-terminal networks in active and passive is discussed.

11. E. F. Bolinder. — Graphical methods for transforming impedances through lossless networks by the Cayley-Klein-Diagram. *Acta Polyt.*, nº 202, 1956.

12. E. F. Bolinder. — The relationship of physical applications of Fourier transforms in various fields of wave theory and circuitry. *Acta Polytechnica*, nº 189, 1956.

13. E. F. Bolinder. — Study of the exponential line by the isometric circle method and hyperbolic geometry. *Acta Polytechnica*, nº 214, 1957.

14. S. Ekelöf, G. Kihlberg (CTH). — Theory of the thermistor as an electric circuit element (A study of thermistor circuits-1). *Trans. Chalmers Inst. Techn.*, nº 142, 1954 (also *Acta Polyt.*, nº 154, 1954).

15. N. Björk, R. Davidson (CTH). — Small signal behaviour of directly heated thermistors (A study of thermistor circuits-2). *Trans. Chalmers Inst. Techn.*, nº 169, 1955 (also *Acta Polyt.*, nº 186, 1955).

16. S. Ekelöf, N. Björk, R. Davidson (CTH). — Large signal behaviour of directly heated thermistors (A study of thermistor circuits-3). *Trans. Chalmers Inst. Techn.*, nº 185, 1957.

17. B. Krüger (KTH). — Power converters with transistors. RVK-1957 (Swedish).

18. P.-O. Leine (KTH). — Amplification versus neutralization at tuned transistor amplifiers. RVK-1957 (Swedish).

19. G. Westerberg (KTH). — A blocking oscillator with *npn*- and *pnp*-transistors. RVK-1957 (Swedish).

20. B.-O. Ås (KTH). — Determination of Q of a resonator by means of impedance measurements and its application in investigating cylindrical surface wave-guides. RVK-1957 (Swedish).

21. A. Dudnik (LME). — A method for the measurement of broad band limiters and an improved limiter. RVK-1957 (Swedish).

22. T. Laurent (KTH). — New types of sections for zig-zag filters. *Ericsson Technics*, nº 12, 1956.

23. T. Laurent (KTH). — The quantum principle for a filter chain. RVK-1957 (Swedish).

24. P. E. Ljung (FOA). — Ferrite materials for Faraday rotation at wavelengths of 3, 6 and 10 cm. RVK-1957 (Swedish). Even *I.E.E. Convention on ferrites* in London, 1956.

25. P. E. Ljung (FOA). — Development of a rotation isolator for 6 cm wavelength. RVK-1957 (Swedish). Even *I.E.E. Convention on ferrites* in London, 1956.

26. H. Schefte (LME). — A frequency filter using different modes in a waveguide. RVK-1957 (Swedish).

27. V. Wentzel (CTH). — The hybrid cascode — a combined transistor and tube amplifier. RVK-1957 (Swedish).

VI-3. — *Electromagnetic Theory (Antennas and Waveguides)*

28. R. Berglund (KTS). — Omnidirectional UHF antenna for vertical polarization. RVK-1957 (Swedish).

29. P.-O. Brundell (KTH). — A new table of the amplitude functions of the iterated sine- and cosine-integrals and some comments on the aperiodic functions in Hallén's antenna theory. *Trans. Roy. Inst. Techn.*, nº 108, 1957.

30. P.-O. Brundell (KTH). — Current and potential distribution on a circular loop antenna. RVK-1957 (Swedish).

31. E. Cassel (KTH). — A new method for measuring phase- and amplitude distribution of antenna currents practised on the reflection free antenna. RVK-1957 (Swedish).

Summary : The report describes a new method for measuring the phase distribution of antenna currents. It is a direct reading method and thus extremely rapid. The accuracy and reproductibility are good.

The design of the coupling between the pick-up loop current and the reference current has previously been a serious problem, but this coupling is here so loose that its influence on the readings can be neglected, as has been demonstrated.

The equipment can be built up of standard components, which makes the cost low.

32. B. Josephson (FOA). — The quarter wave dipole. RVK-1957. (Will be presented at PG of I.R.E. conference at San Francisco, Aug. 1957.)

Summary : A type of dipole antenna has been developed, which at a length of 0.25 to 0.3 times the wavelength is matched to a coaxial line or a twin line. In principle, the antenna may be considered as a special form of a folded dipole (or unipole). If the conductor opposite the fed branch of a conventional folded dipole is broken at the midpoint, resonance occurs at a length of about 0.3. λ, or $\lambda/4$ if a suitable choice of conductor dimensions is made. The radiation resistance is then very low. By applying the feed voltage to a suitable point, a transformation of this resistance to the characteristic impedance value of the feeding cable may be obtained. This may be done without disturbing the symmetry with regard to the feeding cable. The theory of this antenna type is discussed, leading to the impedance properties of unsymmetrically fed dipoles. Dimensions and measuring results referring to antennas fed by a coaxial cable and by a twin line are shown.

The method has been particularly advantageous in designing a very low height, broad band airplane antenna of suitable aerodynamic shape. In this application all radiating and matching elements are made using microstrip technique. Design details and measuring results will be given.

33. E. Hallén (KTH). — Exact treatment of antenna current wave reflection at the end of a tube-shaped cylindrical antenna. *Trans. I.R.E.*, 1956 (Electromagnetic wave theory symposium).

34. R. LINDQUIST (FOA). — A full scale investigation of the influence of the terrain on the radiation properties of some short-wave antennas. RVK-1957 (Swedish).

35. S. NYSTEDT (KTH). — Theoretical investigation of spheroidal antennas, Roy. Inst. Techn., Division of theoretical electrical engineering, Stockholm, 1957.

36. S. SVENNÉRUS (FOA). — Wire antenna in sea water. RVK-1957 (Swedish).

Switzerland

N° 143. - Report of the National Committee to Commission VI

Prof. BALDINGER

An association for the study of the circuits using transistors has been created. The first problem treated by this group is the one of equivalent parameters and circuit diagrams. The circuit diagram proposed by Zawels and Giacoletto (RCA-Review) reveals itself particularly interesting and it could be completed in some points of view (4). With regard to these investigations we point out the realisation of an analog computer for the simulation of the physical phenomena in the transistors (10).

With regard to the circuits using transistors, we point out the investigations made for the application of these elements to the reduction gears and stable-frequency-oscillators (Prof. Dessoulavy, Prof. Baumann) as well as the investigations of Prof. Weber the purpose of wich is the application of transistors to the telephony.

Moreover, some problems relating to television technique have been carried on at the AFIF (ETH) (realisation of saw tooth currents, with high linearity, application of the flyingspot scanner to the control of the uniformity of photoelectric cathodes). Finally we have to point out some investigations on general properties of the circuits (8, 11) on the problems of electric circuits in connection with nuclear physics (5, 6) and on the realisation of an analog photoelectric apparatus destined to the calculation of special integrals (Faltungs-Integrale) (9).

At the Department of High Frequency of the ETH (Prof. Tank)

the investigations mentioned in the last Report (1952-54) were finished ; Pulse Code Modulation using a new method (Margna, Villars, 12, 13), electronic computer for correlation studies (Brumm, 14), Super-Reaction-Systems (Gloor, 15), Radarsystem working with frequency modulation (Ismail, 16), Frequency-modulation for Clystrons (Zito, 17).

The electronic computer for correlation studies has been completed by an additional device, with enlarges the possibilities of application of the computer, mainly in view of statistical phenomena with a slow run.

The radar System using frequency modulation is mainly suitable for measurements on short distances up to some meters, M. Giger has studied the problems relating to antennas and he has published a paper « Studium ueber den Aufbau von Antennengebilden bei vorgegebenem Strahlungsdiagramm » (18). An interesting solution relating to a « Super-Gain antenna » has been found. The ILS System for the airport of Kloten has been improved on the basis of these investigations.

M. Santesmases has studied the problem of the amplitude modulations within the X band with ferrites (19).

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2. E. Baldinger, M. Nicolet. — Untersetzer mit Flächentransistoren. *Z.A.M.P.*, 6, 503, 1955.
3. E. Baldinger, W. Czaja, M. Nicolet. — Ueber das Impulsverhalten von Flächentransistoren. *Z.A.M.P.*, 7, 355, 1956.
4. E. Baldinger, W. Czaja, M. Nicolet. — Der Einfluss nicht idealer Emitterübergänge auf das Verhalten von Flächentransistoren. *Helv. Phys. Acta*, 24, 428, 1956.
5. E. Baldinger, W. Franzen. — Amplitude and Time Measurements in Nuclear Physics, Advances in Electronics and Electron Physics. *Academic Press Inc.*, 8, 255, 1956.
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7. R. Dessoulavy. — Découplage aux basses fréquences de la cathode et de la grille-écran d'un tube amplificateur. *Techn. Mitt. P.T.T.*, 32, 1954, 137.
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12. C. MARGNA. — Eine Ablage für Impuls-Code-Modulation, Mitt.aus dem Inst. für Hochfrequenztechnik der ETH, Zürich, 1954.

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14. G. BRUMM. — Ein elektronischer Correlator. *Diss. ETH*, Zürich, 1954.

15. B. GLOOR. — Studien über einkreisige Schwingungssysteme mit zeitlich veränderlichen Elementen (Zur Theorie und Anwendung des Pendelrückkopplungsempfängers). Mitt. aus dem Inst. für Hochfrequenztechnik der ETH, Zürich, 1955.

16. M. W. ISMAIL. — A Study of the double modulated FM-Radar. Mitt. aus dem Inst. für Hochfrequenztechnik der ETH, Zürich, 1956.

17. G. ZITO. — 723 A/B Reflex Klystron Performance. *Z.A.M.P.*, 5, 252, 1954.

18. G. GIGER. — Studien über den Aufbau von Antennengebilden bei vorgebenem Strahlungsdiagramm. *Diss. ETH*, Zürich, 1956.

19. M. SANTEMASES. — Ueber die Anwendung von Ferriten zur Amplitudenmodulation von Mikrowellen. *Diss. ETH*, Zürich ,1957.

United Kingdom

N° 129. — National Progress Report : Commission VI May 1957

compiled by

W. Proctor WILSON and J. W. HEAD (VI.1 and VI.2)

G. D. MONTEATH : VI.3 (Antennas).

H. M. BARLOW : VI.3 (Guided Waves).

The following report summarizes the progress since about September 1954, in accordance with the new subdivisions VI.1, Communication Theory, VI.2, Circuit Theory, and VI.3, Electromagnetic Theory (Antennas and Waveguides). Items deserving special notice are mentioned in the main text. Where possible

references are given by number to the bibliography which follows. Only sources of information available to the scientific world are quoted as references ; abstracts are sometimes included, especially for items not mentioned in the main text. Work not complete enough for publication is also, where relevant, mentioned in the main text.

VI.1. — Communication Theory

The Third London Symposium on Information Theory was held in the Royal Institution, London, in September, 1955. Papers associated with this symposium were published in reference (1).

Proposals regarding terminology and notation in information theory have been made in a paper by Good (2) with the object of clarifying thought in exposition. The notation proposed does not depend upon the « frequentist » definition of probability as a limiting frequency in an infinite series of trials.

Gouriet (3) has suggested a method of reducing the bandwidth required for a television signal by taking advantage of the fact that in any normal picture there are appreciable plain areas over which the brightness is virtually constant.

Lampard (4) has discussed a method for determining correlation functions of stationary time series by expanding the autocorrelation function in an orthonormal system.

The essay by D. and A. Gabor on the Mathematical Theory of Freedom mentioned in the 1954 bibliography has now been published (5).

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2. Some Terminology and Notation in Information Theory, I. J. Good. *Proc. I.E.E.*, Part C, March 1956, Vol. 103, n° 3, pp. 200-204.

3. G. C. Gouriet. — Bandwidth Compression of a Television Signal. To be published in *Proc. I.E.E.*, Part B.

4. D. G. Lampard. — A New Method of Determining Correlation Functions of Stationary Time Series. *Proc. I.E.E.*, Part C, March 1955, Vol. 102, n° 1, pp. 35-41. Digest, *ibid.*, Part III, Sept. 1954, Vol. 101, n° 73, pp. 343-346.

   The method is based on an expansion of the correlation function in a suitable orthonormal system. The coefficients in the expansion are simply related to the convolution integrals which arise when the given

time series are applied to linear filters whose impulse responses are members of this orthonormal system. A method of measuring these coefficients is proposed. Complex filters can be built up having an impulse response of the same form as the desired correlation function. Examples are presented of filters whose impulse responses are members of a Laguerre system. A practical autocorrelator based on such a filter is described and some results obtained with it are reported.

5. D. and A. GABOR. — An Essay on the Mathematical Theory of Freedom, *Journal of the Royal Statistical Society*, Series A, 1954, Vol. 117, Part I, pp. 31-60. Discussion, pp. 60-72.

VI.2. — CIRCUIT THEORY

(*a*) *Laguerre Functions*

Some attention has been given to the use of Laguerre functions for expressing the time response of linear passive networks to a given excitation. The « natural » or « preferred » excitation and response of certain networks appear to be in the form of Laguerre-function series (2). The conditions for rapid convergence of infinite Laguerre-function series have been discussed by Head (3).

The properties of Laguerre functions themselves have been further investigated by Wilson and Head (4) and (5). Coefficients have also been calculated (6) by means of which a function of time negligible for $t > t_0$ may be expressed immediately as a ten-term series of Laguerre functions if its values at ten times (proportional to the zeros of the tenth-degree Laguerre polynomial) are known or obtainable by graphical or other interpolation.

(*b*) *Derivative equalizer and applications*

The principle of the Gouriet derivative equalizer, to which reference was made in the report for 1952-1954, has been applied (7) to the problem of rotating a single large mass through a given angular distance so that the performance shall meet given specifications. The equalizer principle has also been extended to permit the correction of aperture distortion by active networks having transfer functions of the form

$$a_0 + a_1 \frac{p^2}{p^2 + b^2} + a_2 \frac{p^4}{(p^2 + c^2)(p^2 + d^2)}$$

where $p = i\omega$.

(*c*) *Matrix Algebra. Applications of Matrices*

In network theory, matrices having two rows and two columns are of special interest. Alternative methods of raising such matrices to the *n*th power (as is necessary in problems relating to repeated networks) have been developed by Swift-Hook (8) and by Wilson (9). In the latter case explicit reference to the latent roots is unnecessary.

Matrices associated with four-terminal networks have been applied by Mayo and Head (11) to an investigation of the behaviour of transformers. Matrix analysis has also been used to clarify understanding of the errors likely to be associated with high-frequency bridge measurements (12), and of the way in which the Foster-Seeley discriminator can achieve discrimination with remarkably little distortion.

(*d*) *Network Theory*

The use of delay-line synthesizers for the simulation of linear transfer functions has been described by Westcott (13), and the accuracy of these devices as a system analogue has been studied. The use of delay lines as « quadrature networks » is being studied by Gouriet with promising results.

Talbot (14) has considered fundamental properties of networks by elementary methods which avoid the manipulation of determinants. He draws attention to a neglected paper written by Kirchhoff in 1847 where the foundations of the topology of networks were laid down.

Sander (17) has evolved a method for the approximate determination of the impulse response of a number of « buffered » identical circuits in cascade. By the method of steepest descents, approximate analytical expressions for the time response are obtained. Wilson (2) has studied the time response of a network having several identical dissipative sections each with transfer function of the bilinear form $(ap + b)/(cp + d)$.

(*e*) *Nonlinear Systems*

West and Douce (19) have discussed theoretically the occurrence in the output of a system, of components the frequency of which

is a fraction of the input frequency. A relation is found between the open-loop frequency response and the conditions necessary for subharmonic oscillation. From this, sufficient limitations are obtained to ensure the absence of this phenomenon. Gladwin (20) has considered the stability of non-linear systems with distributed parameters.

(f) Operational Calculus : Impedance Concept : Stability Problems

Mayo and Head (25) have discussed how conditions for the stability of a circuit, and for it to be damped at least as rapidly as $e^{-\alpha t}$, can be deduced from p-domain phenomena without explicit calculation of the corresponding time-world response. Stability of nonlinear systems with distributed parameters has been discussed in the paper by Gladwin (20) already mentioned, and Fuller (26) has considered the analogous problem of conditions for aperiodicity in linear systems.

VI.2. — Bibliography

(a) Laguerre Functions

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3. J. W. Head. — Approximation to Transients by Means of Laguerre Series. *Proc. Camb. Phil. Soc.*, Vol. 52, Part 4, pp. 640-651, 1956.
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6. J. W. Head, G. M. Oulton. — Coefficients for « Decomposition » of Functions into Laguerre-Function Series. BBC Research Department Mathematical Memorandum, n° F-1007, March 1957.

(b) Derivative Equalizer and Applications

7. J. Morris, G. G. Gouriet, J. W. Head. — Servomechanism Performance. *Aircraft Engineering,* July 1955, Vol. 27, n° 317, pp. 220-222.

(*c*) *Matrix Algebra*

8. D. T. Swift-Hook. — The Nth Power of a 2 × 2 Transfer Matrix. *Electronic Engineering,* Nov. 1956, Vol. 28, nº 345, p. 505.

9. W. Proctor Wilson. — Theorems relating to Powers and Continued Products of 2 × 2 Matrices. BBC Research Department Mathematical Memorandum, nº F-1005. To be published in *Electronic and Radio Engineer,* June 1957.

10. M. E. Fisher. — The Matrix Approach to Filters and Transmission Lines. *Electronic Engineering,* May-June 1955, Vol. 27, nºs 327, 328, pp. 198-204, 258-263.

    Use of matrices provides a direct and flexible method of treatment. A simple graphical procedure is indicated for investigating filter characteristics.

11. C. G. Mayo, J. W. Head. — Transformers : General Design Considerations. To be published in *Electronic Engineers'* Reference Book, edited by L.E.C. Hughes and published by Heywood and Co., London.

12. C. G. Mayo, J. W. Head. — Errors in Bridge Measurements. *Wireless Engineer,* Nov. 1956, Vol. 33, nº 11, pp. 265-268.

(*d*) *Network Theory*

13. J. H. Westcott. — The Continuous Delay-Line Synthesizer as a System Analogue. *Proc. I.E.E.,* Part C, Sept. 1956, Vol. 103, nº 4, pp. 357-366.

14. A. Talbot. — Some Fundamental Properties of Networks without Mutual Inductance. *Proc. I.E.E.,* Part C, Sept. 1955, Vol. 102, nº 2. pp. 168-175.

15. G. V. Buckley. — Parallel-T RC Network. *Wireless Engineer,* July 1956, Vol. 33, nº 7, pp. 168-173.

    A simplified design method is presented based on finding an equivalent network which is more amenable to mathematical treatment.

16. D. D. Crombie. — The Design of Low-Frequency High-Pass RC Filters. *Electronic Engineering,* June 1956, Vol. 28, n º 340, pp. 254-256.

    The design of a twin-T network incorporated in a feedback amplifier circuit is discussed and details are given relating frequency response to phase shift in the amplifier. The use of compensating sections for securing a flat pass-band characteristic is considered and a practical example is worked out.

17. K. F. Sander. — A Method for the Approximate Determination of the Impulse Response of a number of Identical Circuits in Cascade. *Proc. I.E.E.,* Part C, Vol. 104, nº 5, March 1957, pp. 13-24.

18. W. K. R. Lippert. — New Filter Theory of Periodic Structures. *Wireless Engineer,* Oct., Nov. 1955, Vol. 32, nºs 10, 11, pp. 260-266, 305-310.

Theory for linear passive quadripoles is developed in terms of characteristic reflection and transmission factors which can be specified by reference to the standing-wave pattern on lines connected to the input and output.

(e) Non-linear Systems

19. J. C. West, J. L. Douce. — The Mechanism of Sub-harmonic Generation in a Feedback System. *Proc. I.E.E.*, Part B, Sept. 1955, Vol. 102, n° 5, pp. 569-574. Discussion, pp. 594-595.

20. A. S. Gladwin. — Stability Criteria for an Electrical or Mechanical System with Distributed Parameters. *Brit. J. appl. Phys.*, Nov. 1955, Vol. 6, n° 11, pp. 400-402.

For electrical or mechanical systems with distributed parameters, or with an element producing a finite time delay, to be stable all the roots of the appropriate characteristic equation must be negative or have negative real parts. If the equation is expressed in the form :

$$C_0 + C_1 z + (C_2 + C_3 z) \tanh z = 0$$

then for C_0 positive, C_1 and C_3 must be positive and C_2/C_1 must be greater than a certain critical value which is a function of C_0/C_3. An example is given of the application of these criteria to a servomechanism.

21. P. E. W. Grensted. — The Frequency-Response Analysis of Non-linear Systems. *Proc. I.E.E.*, Part C, Sept. 1955, Vol. 102, n° 2, pp. 244-253 ; Digest, *ibid.*, Part B, Sept. 1955, Vol. 102, n° 5, pp. 721-723.

If the waveform at the input to the non-linear elements in the system is approximately sinusoidal, the analysis may be carried out on the assumption that all harmonics generated by the non-linear elements can be ignored. Analysis of on-off control systems on this basis gives results within about 10 percent of the exact solutions for both transient and steady oscillations.

22. W. E. Thomson. — The Response of a Non-linear System to Random Noise. *Proc. I.E.E.*, Part C, March 1955, Vol. 102, n° 1, pp. 46-48 ; Digest, *ibid.*, Part III, Nov. 1954, Vol. 101, n° 74, p. 407.

A simplified form is derived of a formula obtained previously (see e. g. 3238 of 1948 (Middleton)) for the autocorrelation function of the output of a non-linear system for the case where the output/input relation is expressed as a power series. The new formula emphasizes that intermodulation products of different orders are uncorrelated while contributions to the intermodulation product of a given order from different terms of the power series are completely correlated. If the output is expressed as a series of Hermite polynomial functions of the input, each term of the series gives rise to intermodulation products of one order only.

23. E. B. Moullin. — The Solution of a Certain Differential Equation. *Proc. I.E.E.*, Part IV, Aug. 1954, Vol. 101, n° 7, pp. 290-299 ; Digest, *ibid.*, Part I, July 1954, Vol. 101, n° 130, pp. 204-206.

A method of obtaining approximate solutions to a class of non-linear network problems is discussed. The method was developed in relation to the problem of a capacitor in series with a non-linear resistor of the SiC type, and its application is illustrated by reference to this problem, the resistor characteristic being assumed cubic and the applied voltage simple harmonic. An exact steady-state solution for this network is unobtainable, but an approximate solution is obtained by choosing the constants in the formula for the voltage across the resistor such that the applied voltage has no third-harmonic component.

24. T. S. Fox, K. R. Sturley. — The Voltage Ratio and Output Impedance of a Ladder Network composed of *n* Similar Elements. *Electronic Engineering*, Oct. 1954, Vol. 26, nº 320, pp. 447-448.

Simple expressions are derived using Thévenin's theorem.

(f) Operational Calculus. Impedance Concept. Stability

25. C. G. Mayo, J. W. Head. — The Impedance Concept. *Wireless Engineer'* April-May 1956, Vol. 33, nºs 4, 5, pp. 96-102, 121-128.

26. A. T. Fuller. — Conditions for Aperiodicity in Linear Systems. *Brit. J. Appl. Phys.*, June 1955, Vol. 6, nº 6, pp. 195-198.

The necessary and sufficient conditions are derived ; when expressed in terms of the coefficients of the characteristic equation they take the form of a number of simple determinantal inequalities which are closely analogous to the Routh-Hurwitz stability criteria.

27. L. Tasny-Tschiassny. — Nyquist's Criterion for Multiple-Loop Feedback Circuits. *Wireless Engineer*, April 1955, Vol. 32, nº 4, pp. 114-115.

A method of deriving the stability criterion alternative to that of Cutteridge (3489 of 1954) and based on conformal transformation is presented. See also 72 of January, 1955 (Cutteridge).

VI.3. — Electromagnetic Theory (Antennas)

The most important characteristic of an aerial is its radiation pattern, and much of the basic work carried out in the period under review has been concerned with this aspect of aerial performance.

Bates and Elliott (1) have studied the relationship between the sidelobe level in the radiation pattern of a long broad-side array measured in the Frauenhofer region and the radiation pattern measured in the Fresnel region. The results of this work enable measurements to be made at a shorter distance than would otherwise be necessary.

Brown and Spector (2) have proposed a new approach to the theoretical study of a class of end-fire aerials, including Yagi

aerials and dielectric rod aerials, in which waves are guided from the feed point along a retarding structure and launched from the end. Their treatment appears to give a more satisfying physical picture of the action of these aerials than methods previously adopted.

Johnson (3) has studied the « notch » aerial, which may be regarded as the slot analogue of a unipole mounted co-planar with and perpendicular to the edge of a semi-infinite metal sheet. A short unipole mounted in this way is unusual in that the radiation resistance is proportional to the length instead of to the square of the length, as is the case with a unipole mounted above a ground plane. The notch aerial has a number of advantages in its application to aircraft.

Brick (4) has investigated the vertical radiation pattern of a unipole placed above or within a dielectric coating on a conducting sheet. This exhibits a singularity in the plane of the sheet corresponding to a surface-guided wave.

A paper by Page and Monteath (5) summarizes a theoretical and experimental investigation into the vertical radiation patterns of aerials used for medium-wave broadcasting. Imperfectly-understood factors which made this investigation necessary included the current distribution along the aerial, the effect of an earth system upon its radiation pattern and the uneven surface of the ground. In addition, the radiation pattern is effectively blurred by diffuse reflection at the ionosphere.

In the B. B. C. Research Department, a theoretical investigation into the effect of earth systems on the performance of medium-wave aerials, which was referred to in the report presented to the meeting at The Hague, has been continued, and two boundary value problems have been investigated in further detail. One is concerned with the difference between a thin metal disk laid upon the ground and a semi-infinite cylindrical block embedded in it. An approximate solution obtained by means of dual integral equations leads to the conclusion that the two types of earth system behave similarly apart from a transverse line impedance at the edge of the disk. As one step in the consideration of radial wire earth systems, an expression has been derived for the impedance at normal incidence of an infinite wire grating in the interface between two semi-infinite media.

A problem frequently encountered is the determination of the horizontal radiation pattern of an array of dipoles supported on a conducting mast of uniform cross-section. The solution for cylindrical masts has long been known, but in fact a triangular or square cross-section is more commonly used. A small polygonal mast can be treated in terms of an equivalent cylinder. On the other hand, the effect of reflection from the faces of a very large polygonal mast can be determined by geometrical optics, i. e., by the use of images. For masts of intermediate size, an approximate solution is under investigation in the B. B. C. Research Department. This method is similar, but not identical, to the use of the classical diffraction theory, and may therefore be treated as a second approximation for large masts, the use of images being a first approximation.

VI.3 — Bibliography (Antennas)

1. R. H. T. Bates, J. Elliott. — The Determination of the True Side-Lobe Level of Long Broadside Arrays from Radiation-Pattern Measurements in the Fresnel Region. *Proc. I.E.E.*, Vol. 103, Part C, nº 4, p. 307, Sept. 1956.

   The radiation pattern in the Fresnel region is expressed as a function of the far field polar diagram. Following this it is shown how the true side-lobe level may be inferred from amplitude radiation-pattern measurements made in the Fresnel region. This results in considerable shortening of the range at which polar-diagram measurements may be made.

2. J. Brown, J. O. Spector. — The Radiating Properties of End-Fire Aerials. *Proc. I.E.E.*, Vol. 104, Part B, nº 13, p. 27, Jan. 1957.

   An end-fire aerial, such as a Yagi or dielectric-rod aerial, can be regarded as a structure which supports the dipole type of surface wave. Radiation occurs at the end of the aerial, the radiation pattern being determined by the transverse filed distribution of the surface wave. It is shown that this leads to a simple relation between the beam width of the pattern and the ratio of the wavelength of the surface wave to that in free space. Further, this approach shows that the beam width tends to a non-zero value as the aerial length increases, in contrast with previous theories which predict that it decreases to zero with increasing length. In applying the theory to practical aerials, allowance must be made for the radiation which also occurs from the end of the aerial at which the surface wave is excited. Theoretical and experimental patterns for several end-fire aerials are compared, and it is shown that good agreement can be obtained.

3. W. A. JOHNSON. — The Notch Aerial and some Applications to Aircraft Radio Installations. *Proc. I.E.E.*, Part B, Vol. 102, pp. 211-218 March 1955.

   Analysis and experiments show that metallic sheets with notches cut perpendicular to an edge can make very efficient antennas. Wide-band characteristics can be obtained with a notch about $\lambda/4$ deep, but the detail of the polar diagram may vary with frequency, depending on the shape and size of the sheet. Notches short compared with the wavelength — termed « nitches » — can be operated either as fixed-tuned narrow-band antennas, or, in association with a tuning unit, over a wider band. For reception at frequencies around 100 Mc/s a notch of length about 3 inches is adequate. Tests made with aircraft tail fins and wings are described ; HF, VHF and UHF types are practical.

4. D. B. BRICK. — The Radiation of a Hertzian Dipole over a Coated Conductor. *Proc. I.E.E.*, Part C, Vol. 102, pp. 104-121, March 1955.

   The study presented was undertaken in an effort to explain certain characteristics of an antenna field pattern measured over an aluminium ground screen presumed to have a thin coating of aluminium oxide. Analysis is given for the case where the dipole is (*a*) above the dielectric coating, (*b*) in the dielectric coating, and (*c*) lying in the conductor-dielectric interface. Values of the field potentials are obtained for both electric and magnetic dipoles. The power from the dipole is partly radiated and partly surface-guided ; numerical values for the ratio between the two are derived for some particular cases.

5. H. PAGE, G. D. MONTEATH. — The Vertical Radiation Patterns of Medium-Wave Broadcasting Aerials. *Proc. I.E.E.*, Part B, Vol. 102, pp. 279-295, May 1955. Discussion, pp. 295-297.

   It is common practice to use vertical antennas of height 0.5 λ-0.6 λ so as to reduce the strength of the wave reflected by the ionosphere and thus increase the fading-free range. Results of experiments on small-scale and full-scale radiators indicate that, for an antenna on a flat uniform site, if the ionosphere behaved like a smooth reflector a larger service area would result from loop feeding than from base feeding ; further improvement is obtainable by double feeding, the magnitude of the improvement being greater the lower the ground conductivity. The effect of earth systems is mainly to improve efficiency. Irregularity of the ground at the transmitter site causes distortion of the vertical radiation pattern, while diffuse reflection at the ionosphere produces an effect equivalent to blurring of the pattern. Computed patterns based on a semi-empirically determined current distribution are in reasonably good agreement with the experimental results.

6. J. W. CROMPTON. — On the Optimum Illumination Taper for the Objective of a Microwave Aerial. *Proc. I.E.E.*, Part III, Vol. 101, pp. 371-382 ; Nov. 1954.

The Fourier-transform description of the radiation pattern from an aperture is used to obtain curves relating to over-all gain of an idealized antenna system, comprising an objective and wave-guide flare, with the size and illumination of the aperture of the latter. For rectangular objectives the dimensions of the aperture of the flare may be varied independently in the two planes of symmetry and the over-all gain obtained by multiplying together the gain factors for the distributions across the objective in these two planes.

In the case of the circular objective this no longer applies, but curves are drawn showing the variation of the gain of the system as the size of a symmetrical feed is varied by equal amounts in the two planes of symmetry. It is shown that maximum over-all gain is obtained with a rectangular objective when the size of the feed is adjusted to give a primary pattern such that the illumination intensity at the edges of the objective is 8½ db below that at the centre. The corresponding optimum taper for circular objectives is 11½ db.

Primary radiation-patterns are drawn for « constant », « cosine » and « double-cosine » illuminations of the feed aperture. The variations of secondary beam-widths and first side-lobe levels with feed size for rectangular and circular objectives are discussed.

VI.3. — Electromagnetic Theory (Waveguides)

Under the above heading it is proposed to include work concerned with (i) propagation along the inside of hollow metal channels, (ii) surface waves, including the single wire transmission line and waves supported by flat surfaces, (iii) coaxial lines, and (iv) strip lines.

(i) *Hollow metal waveguides*

The effect of surface roughness on the attenuation of waveguides operated at between 9000 and 10 000 Mc/s has been studied by Allison and Benson (1), who for this purpose developed a technique of examining in detail the wall contour and correlating this with the extended path of the current. A systematic investigation was made of precision drawn, chemically polished, electropolished, electroplated and electroformed waveguides, giving useful information about their relative performances. The expressions derived by Kuhn for calculating attenuations in rectangular guide were modified to take into account the surface roughness. More recently, the same authors (2) have extended their measurements of attenuation to waveguides constructed of ferromagnetic metals and thus obtained figures for the relative permeability in the 3 cm

wave-band of nickel, mild steel, mumetal, radio-metal and rho-metal. It appears that mild steel retains its ferro-magnetic properties more persistently than the other metals examined.

Closely allied to this work are the investigations made by Harvey (3) into electroforming processes for producing waveguide components of complicated design and his plan (4) to establish a comparator scale based on skin depth for different surface finishes. Lewin (5) has analysed propagation in curved and twisted waveguides of rectangular cross-section by putting the wave equation into a form in which the co-ordinates are also the independent variables. Changes in guide wavelength for E plane and H plane bends, and for twisted sections were deduced. Butcher (6) has put forward a new treatment of propagation in lossy periodic waveguides which has the advantage that it provides more precise information about the phase change coefficient and is applicable over a wide range of frequencies when the losses are small. Karbowiak (7) has investigated propagation in anisotropic waveguides based on the surface impedance approach of some of his earlier work (8). In particular, he deals with corrugated and conducting helix waveguides showing that only certain wave modes remain stable when their principal axes differ from the co-ordinate axes of the surface. Allen and Clarke (9) have tackled the problem of interpreting wavelength measurements on tape helices and their results indicate that the unexpected region of dispersion observed by Sensiper is due to the finite length of the helix.

Work on axially unsymmetrical waveguide junctions has been carried out by Collin and Brown (10) and by Farmer (11). In both cases the problem was approached in terms of an equivalent circuit and some degree of symmetry is shown to be helpful in yielding solutions of important application. The first authors apply the variational method developed by Schwinger and show that this can also be used for asymmetrical junctions. Calculations for a junction between an air-filled guide and one partially filled with dielectric were employed to illustrate the method. In a subsequent paper (12) by the same authors, this kind of junction was shown to provide the basis for a quarter-wave matching transformer between two lengths of guide, one of which is empty and the other completely filled with dielectric. An ingenious waveguide phase

changer of a new type has also been developed by Collin (13). In this instrument the phase shift is produced by longitudinal displacement of a central dielectric strip in a rectangular waveguide with fixed side dielectric strips. A standing wave ratio less than 1.05 with a departure from linearity smaller than 1° was achieved over a range of wavelengths 3 to 3.5 cm.

(ii) *Surface waves*

Cullen (14) has examined the problem of launching a plane surface wave over a horizontal flat surface using a line source parallel with the surface. In particular, he discusses the case of a narrow radiating slot above a corrugated or dielectric coated metal plate and concludes that launching efficiencies of the order of 80 percent should be possible for a particular height of the slot above the plate. The direct and indirect components of the radiation field than cancel one another, leaving only the surface wave. Fernando and Barlow (15) who extended Cullen's work to the radial form of surface wave supported by a flat reactive surface consisting of a metal plate either corrugated or dielectric coated, have obtained experimental confirmation of the theoretical results. Rich (16) made a similar investigation using a variety of launching devices, but he was unable to obtain efficiencies greater than 50 percent which was achieved with a « double-cheese » aerial. He concluded that a large aperture required an exponential distribution of the field over it in order to produce a high launching efficiency.

In 1953 Barlow and Cullen (17) had predicted theoretically that a capacitive surface of cylindrical form should, in appropriate circumstances, be capable of supporting an axial surface wave of the kind associated with a single wire transmission line. Previously only inductive surfaces had been considered to meet the requirements. By experimenting with a perspex rod acting as a waveguide, the diameter of which was reduced in stages to enable the transition from an inductive to a capacitive surface to be observed, Barlow and Karbowiak (18) were able to confirm the existence of a surface wave on the capacitive surface and that it had a phase velocity greater than that of light.

As a variant of the usual form of cylindrical surface wave, Karbowiak (19) has examined the case of a guide of elliptical cross-section. In this way he has shown that small deformations

of a circular section guide leave the associated surface wave substantially unaffected.

(iii) *Coaxial lines*

Blackband (20) has made a useful survey of coaxial cable parameters and discussed the best compromise between the various quantities for different applications. Special consideration was given to attenuation per unit length, voltage and power ratings based on thermal and electric stress limitations. He concluded that for low-loss air-space cables the best value of characteristic impedance is 75 ohms and for general-purpose thermoplastic cable, 50 ohms.

Non-uniform transmission lines as impedance transformers have been considered afresh by Willis and Sinha (21) and as a result important design information for optimum performance as matching sections has been obtained. A compensated coaxial-line-resistor termination giving negligible reflection over a wide band of frequencies was described (22). Harris (23) has tackled a similar problem from a somewhat different standpoint. He set out to design a coaxial resistor which would not only retain its d. c. resistance without appreciable reactance at all frequencies up to about 4000 Mc/s, but would also be capable of a substantial power rating. His work led to the construction of a uniform cylindrical film resistor with a critically dimensioned outer conductor, the profile of which took the form of a tractrix. Experimental results show an impedance within 1 percent of the d. c. resistance at all frequencies up to 3450 Mc/s. Coupled transmission lines as symmetrical directional couplers have been studied by Monteath (24). Two similar unbalanced transmission lines were coupled together by sharing a common outer conductor for part of their length, so as to form a three-conductor line. With this arrangement, the output ratio varies sinusoidally with frequency when different coupling lengths are used, but the characteristic impedance is independent of frequency. Such couplers may very conveniently be used for power measurements up to frequencies of 1000 Mc/s.

(iv) *Strip lines*

In the application of strip-line technique, calculations for the line parameters are not very reliable, particularly for the range

of characteristic impedances between 20 and 150 ohms. Dukes (25) has made a comprehensive investigation of the behaviour of the balanced-parallel-plate line, the strip-above-ground line and the sandwich line, with the aid of an electrolytic tank, and new methods of calculating the line parameters have thereby been developed.

VI.3 — Bibliography (Waveguides)

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3. A. F. Harvey. — *Proc. I.E.E.*, Part B (1955), 102, pp. 223, 493.
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5. L. Lewin. — *Proc. I.E.E.*, Part B (1955), 102, p. 75.
6. P. N. Butcher. — *Proc. I.E.E.*, Part B (1956), 103, p. 301.
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9. C. P. Allen, G. M. Clarke. — *Proc. I.E.E.*, Part C (1956), 103, p. 171.
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11. E. D. Farmer. — *Proc. I.E.E.*, Part C (1956), 103, p. 145.
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16. G. J. Rich. — *Proc. I.E.E.*, Part B (1955), 102, p. 237.
17. H. M. Barlow, A. L. Cullen. — *Proc. I.E.E.*, Part III (1953), 100, p. 329.
18. H. M. Barlow, A. E. Karbowiak. — *Proc. I.E.E.*, Part B (1955), 102, p. 313.
19. A. E. Karbowiak. — *Brit. Journal Applied Physics* (1954), 5, p. 328.
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21. J. Willis, N. K. Sinha. — *Proc. I.E.E.*, Part B (1956), 103, p. 166.
22. J. Willis, N. K. Sinha. — *Wireless Engineer* (1956), 33, p. 204.
23. I. A. Harris. — *Proc. I.E.E.*, Part C (1956), 103, p. 1.
24. G. D. Monteath. — *Proc. I.E.E.*, Part B (1955), 102, p. 383.
25. J. M. C. Dukes. — *Proc. I.E.E.*, Part B (1956), 103, p. 319.

U. S. A.

N° 300. — Report of the National Commission VI

6.1. — Recent U. S. work on Information Theory and Communication Theory

Introduction

Communication theory began to develop perhaps three or four decades ago as a means for predicting the performance of telegraph and radio communication systems. As such, it grew out of electric-circuit theory, which had already found elegant means for expressing the steady-state response of a linear device to a sinusoid. Thus, communication theory dealt largely at first with the Fourier representation of signals and later of noise also, and it applied these in the study of the effects of non-linear devices as well as linear. More recently the problem of designing a communication system has been recognized as the problem of filtering the received signal and the concomitant noise in such a way as to recover the best (in some sense) possible approximation to the transmitted signal and of choosing such a type of signal to transmit that this best approximation is optimized. When the filter is non-linear, it is generally called a detector, but in principle the problems of signal detection and filtering are similar. The problem of predicting the future values of a random signal is also closely related to that of filtering.

In the past decade the notion of « amount of information » has been introduced as a measure of the value of a signal detector or, more generally, of a communication system. This notion — more precisely, the amount of information about the transmitted message which is contained in the received message — has given rise to a new field within communication theory called « information theory », which characterizes communication systems according to their information rates. The choice of the optimum signals to transmit, i. e., the optimum representation for the transmitted messages, is often called the coding problem, especially in the context of information theory.

While the older concepts of communication theory have applications outside of electronics — for example, to mechanical and

acoustical systems — the more general and abstract approach of information theory can be applied in the behavioral sciences as well, e. g., in the study of the information rates of human beings and the information-theoretical properties of human language, although the usual difficulties that plague measurement in the behavioral sciences still remain.

Thus, communication theory may be viewed as including the study of the characteristics of signals and noise as they are affected by communication systems, the best signals to transmit, and the best means for filtering and detection ; it also includes information theory, which treats information rates and the coding of messages.

U. S. Journals

All of these aspects have received attention in the United States. The principal journals in which the American work in information theory and communication theory is published are : the *IRE (Institute of Radio Engineers) Transactions on Information Theory*, the *IRE Convention Record*, the *IRE Wescon Convention Record*, the *Bell System Technical Journal*, the new international journal *Information and Control*, and occasional articles in the *Proceedings of the IRE*, the *Annals of Mathematical Statistics*, and the *IRE Transactions on Circuit Theory*, on *Electronic Computers*, and on *Automatic Control*. The *Journal of Applied Physics* formerly carried occasional articles in this field. In addition, a considerable amount of work in information and communication theory appears in the form of technical reports of the laboratories in which it is done.

Recent papers

Some idea of what has been going on recently in the field of communication theory in the United States may be provided by an annotated list of the papers published in the quarterly *IRE Transactions on Information Theory* since the beginning of 1956, i. e., in volume IT-2 (1956), numbers 1 through 4, and volume IT-3 (1957), number 1.

Information Theory

General. — Among the U. S. papers dealing with the basic notions of information and information rate are :

« A New Interpretation of Information Rate », by John L. KELLY, Jr., of the Bell Telephone Laboratories, Vol. I.T.-2, nº 3, p. 185, viz. — The expected rate of increase of he logarithm of a gambler's capital when the odds are fair but the receives information over a private wire and places his bets so as to maximize this quantity. This interpretation gives significance to the information rate even though no coding is contemplated.

« The Zero-Error Capacity of a Noisy Channel », by Claude E. SHANNON (formerly of the Bell Telephone Laboratories and now of the Massachusetts Institute of Technology), Vol. I.T.-2, nº 3, p. 8, viz. — The least upper bound of rates at which it is possible to transmit information with zero probability of error. Shannon studies various properties of this capacity and also shows that, whereas the addition of feedback to a memoryless channel cannot increase its ordinary capacity, it may increase its zero-error capacity.

« A Note on the Maximum Flow through a Network », by Peter ELIAS of the Massachusetts Institute of Technology (M.I.T.), Amiel FEINSTEIN of M.I.T.'s Lincoln Laboratory, and Claude SHANNON, Vol. I.T.-2, nº 4, p. 117, which shows that the maximum possible rate of information flow from left to right through a network equals the minimum value among all simple cut sets. A cut set is defined as a set of branches which, when removed from the network, leaves no connection 'rom the left terminal to the right ; it is called « simple » if it is no longer a cut set when any branch is omitted. Its « value » is the sun of its left-to-right capacities.

« Merit Criteria for Communication Systems », by A. HAUPTSCHEIN and L. S. SCHWARTZ (New York University), Vol. I.T.-3, nº 1, p. 52. — The criterion is the cost of transmitting a message.

« Theory of Information Feedback Systems », by S. S. L. CHANG of New York University, Vol. I.T.-2, nº 3, p. 29.

Coding. — Although coding is not always related directly to information theory, the papers dealing with it are conveniently listed here :

« A Note on Two Binary Signaling Alphabets », by David SLEPIAN (Bell Telephone Laboratories), Vol. I.T.-2, nº 2, p. 84, which treats error-correcting codes and maximum-likelihood detection.

« A Linear-Circuit Viewpoint on Error-Correcting Codes », by D. A. HUFFMAN (M.I.T.), Vol. I.T.-2, nº 3, p. 20. — Huffman represents a linear binary filter with feedback by a rational function of a delay operator. Such a filter can generate the redundant digits needed in an error-correcting code and can locate errors.

« Two Inequalities Implied by Unique Decipherability », by Brockway MCMILLIAN (Bell Telphone Laboratories), Vol. I.T.-2, nº 4, p. 115.

« Some Optimal Signals for Time Measurement », by Herbert SHERMAN (M.I.T. Lincoln Laboratory), Vol. I.T.-2, nº 1, p. 24.

« A Linear Coding for Transmitting a Set of Correlated Signals », by H. P. KRAMER and M. V. MATHEWS (Bell Telephone Laboratories), Vol. I.T.-2, nº 3, p. 41. — The coding involves finding a (smaller) set of uncorrelated signals of which the original set are (approximated by) linear combinations. In this way, the channel-capacity requirements can be reduced.

Human Information Capacities. — The capacity of the human being in processing information is treated in :

« Human Memory and the Storage of Information », by George MILLER (Harvard University), Vol. I.T.-2, nº 3, p. 129. — Miller finds that people can remember about seven characters, almost regardless of the size of the alphabet from which they come.

« Some Studies in the Speed of Visual Perception », by George SZIKLAI (RCA Laboratories), Vol. I.T.-2, nº 3, p. 125. — These studies indicate an information rate of thirty to fifty bits per second over spans of one tenth to two seconds.

Detection, Filtering, and Prediction of Signals

Detection. — Although it is sometimes difficult to distinguish detection from filtering, the following papers may be said to deal with detection :

« The Output Signal-to-Noise Ratio of Correlation Detectors », by Paul E. GREEN, Jr. (M.I.T. Lincoln Laboratory), Vol. I.T.-3, nº 1, p. 10.

« Optimum Detection of Random Signals in Noise, with Application to Scatter-Multipath Communication », by Robert PRICE (M.I.T. Lincoln Laboratory), Vol. I.T.-2, nº 4, p. 125.

« The Human Use of Information III. Decision-Making in Signal Detection and Recognition Situations involving Multiple Alternatives », by John A. SWETS and Theodore G. BIRDSALL (University of Michigan), Vol. I.T.-2, nº 3, p. 138.

« Determination of Redundancies in a Set of Patterns », by Arthur GLOVAZKY (Raytheon Manufacturing Co.), Vol. I.T.-2, nº 4, p. 151.

« Automatic Bias Control for a Threshold Detector », by J. DUGUNDJI and Erik ACKERLIND (Radio Corporation of America), Vol. I.T.-3, nº 1, p. 65.

Radar. — The following papers deal with the problems of radar detection.

« Effects of Signal Fluctuation on the Detection of Pulses Signals in Noise », by Mischa SCHWARTZ (Polytechnic Institute of Brooklyn), Vol. I.T.-2, nº 2, p. 66.

« A Coincidence Procedure for Signal Detection », also by Mischa SCHWARTZ (*loc. cit.*), Vol. I.T.-2, n° 4, p. 135.

« A Radar Detection Philosophy », by William McC. SIEBERT (M.I.T.). Vol. I.T.-2, n° 3, p. 204.

« An Analysis of Signal Detection and Location by Digital Methods », by Gerald P. DINEEN and Irving S. REED (M.I.T. Lincoln Laboratory), Vol. I.T.-2, n° 1, p. 29.

« Inverse Probability in Angular-Tracking Radars », by Behrend J. DUWALDT (Ramo-Wooldridge Corp.), Vol. I.T.-2, n° 1, p. 38.

Filtering and Prediction. — Filtering is the subject of.

« Optimum Linear Discrete Filtering of Signals containing a Nonrandom Component », by Kent R. JOHNSON (University of Pittsburgh), Vol. I.T.-2, n° 2, p. 49.

« Spatial Filtering in Optics », by Edward L. O'NEILL (Boston University), Vol. I.T.-2, n° 2, p. 56.

« On Optimum Non-linear Extraction and Coding Filters », by A. V. BALAKRISHNAN and R. DRENICK (Radio Corporation of America), Vol. I.T.-2, n° 3, p. 166.

« Exact Integral-Equation Solutions and Synthesis for a Large Class of Optimum Time-Variable Linear Filters », by Julius S. BENDAT (Ramo-Wooldridge Corp.), Vol. I.T.-3, n° 1, p. 71.

« On the Estimation in the Presence of Noise of the Impulse Response of a Random Linear Filter », by George L. TURIN (Hughes Aircraft Co.), Vol. I.T.-3, n° 1, p. 5. The filter Turin discusses is a transmission medium ; he determines both the optimum linear estimating filter in the receiver for a given sounding signal and the optimum sounding signal to be transmitted.

Prediction is dealt with in.

« Generalization of the Class of Non-random Inputs of the Zadeh-Ragazzini Prediction Model », by Marvin BLUM (Convair), Vol. I.T.-2, n° 2, p. 76.

« An Extension of the Minimum Mean-Square Prediction Error Theory for Sampled Data », by Marvin BLUM, Vol. I.T.-2, n° 3, p. 176.

Signal Statistics

The statistical characteristics of signals and noise are discussed in.

« The Correlation Function of a Sine Wave plus Noise after Extreme Clipping », by J. A. MCFADDEN (Naval Ordnance Laboratory), Vol. I.T.-2, n° 2, p. 82. — For the case of strong gaussian noise, McFadden finds an approximation to the correlation function.

« The Axis-Crossing Intervals of Random Functions », by J. A. McFadden, Vol. I.T.-2, nº 4, p. 146. — This paper relates the probability density of the interval between successive axis crossings of any stationary ergodic process to the autocorrelation function of the process obtained by extreme clipping. The expected number of zeros per unit time is found to equal half the left-hand derivative at the origin of the norma lized autocorrelation function. If this autocorrelation function is nearly linear for small arguments, the axis-crossing-interval distribution is proportional to its second derivative in the same range.

« A Systematic Approach to a Class of Problems in the Theory of Noise and Other Random Phenomena-Part I », by Donald A. Darling (University of Michigan) and Arnold J. F. Siegert (Northwestern University), Vol. I.T.-3, nº 1, p. 32.

« A Systematic Approach to a Class of Problems in the Theory of Noise and Other Random Phenomena-Part II, Examples », by Arnold J. F. Siegert, Vol. I.T.-3, nº 1, p. 38.

« First-Order Markov Process Representation of Binary Radar Data Sequences », by George C. Sponsler (Office of Naval Research), Vol. I.T.-3, nº 1, p. 56.

« On a Cross-Correlation Property for Stationary Random Processes », by John L. Brown, Jr. (Pennsylvania State University Ordnance Research Laboratory), Vol. I.T.-3, nº 1, p. 28.

« The Measurement of Third-Order Probability Distributions of Television Signals », by W. F. Schreiber (Technicolor Corp.), Vol. I.T.-2, nº 3, p. 94. — Schreiber describes his apparatus and presents examples of second- and third-order distributions together with their calculated entropies.

Miscellaneous

The following papers deal with probability, mathematics, logic, control systems, the simulation of the brain, and linguistics.

« Generating a Gaussian Sample », by Seymour Stein (Hycon Eastern) and James E. Storer (Harvard University), Vol. I.T.-2, nº 2, p. 87. — This paper discusses the generation of a discrete process having a specified power spectrum for use in Monte-Carlo calculations.

« Solution of an Integral Equation Occurring in Theories of Prediction and Detection », by Kenneth S. Miller (New York University) and Lofti A. Zadeh (Columbia University), Vol. I.T.-2, nº 2, p. 72.

« The Logic Theory Machine », by Allen Newell and Herbert A. Simon (RAND Corporation), Vol. I.T.-2, nº 3, p. 61. — The authors have programmed a general-purpose digital computer to find proofs for theorems in symbolic logic in a manner simulating human problem-solving efforts.

« Final-Value Systems with Gaussian Inputs », by Richard C. Booton, Jr. (M.I.T.), Vol. I.T.-2, nº 3, p. 173. — This paper is concerned with the optimum control system for achieving a final value for a variable when its time derivative is limited in absolute value. Booton finds it best to use only plus or minus this value for the velocity when the joint distribution of the input and the desired response is gaussian.

« Tests of a Cell-Assembly Theory of the Action of the Brain, using a Large Digital Computer »,by N. Rochester, J. H. Holland, L. H. Haibt and W. L. Duda (I.B.M. Research Laboratory), Vol. I.T.-2, nº 3, p. 80. — On the I.B.M.-704, the formulation of cell assemblies from an unorganized net of neurons was simulated.

« Three Models for the Description of Languages », by A. Noam Chomsky (M.I.T.), Vol. I.T.-2, nº 3, p. 113. — Dealing with schemata for the construction of sentences.

« Gap Analysis and Syntax », by Victor H. Yngve (Massachusetts Institute of Technology), Vol. I.T.-2, nº 3, p. 106. — The constraints that operate between words in a language are here studied by means of histograms showing the frequency of gaps of various lengths between occurrences of one specific word and another in texts.

Conclusions

In addition to the foregoing, a number of other excellent papers written by foreign scientists — many visiting the U. S. — have appeared in the *IRE Transactions on Information Theory*. They have been omitted here lest it be thought that their works are claimed as American.

While the largest proportion of the U. S. publications in the field of information theory appears in the *Transactions*, it must be remembered that a good deal is published in other journals, most notably the *Bell System Technical Journal*, and that some is published abroad. Nevertheless, the sample above gives a good indication of the range of interests among American information theorists, which includes measures of information, coding, human information capacities, the detection of signals in noise, radar, filtering, prediction, signal statistics, and the related mathematics and applications - applications particularly in the fields of thought processes and linguistics.

6.2. — Circuit Theory

This report briefly surveys the progress made in the United States since 1954 in the field of Circuit Theory. The biblio-

graphies presented in the following sections are largely selections of representative papers in each area and are by no means complete.

The three year period under survey was marked by a gradual, but steadily accelerating, shift of interest from classical RLC network synthesis problems to essentially « systems » problems centering on the input-output analysis of « black boxes » and their interconnections. Indeed, some observers feel that circuit theory is now evolving into a broader discipline — system theory. This trend is evidenced by the composition of subject matter of the IRE Transactions on Circuit Theory. Specifically, out of 118 papers which appeared in the Transactions since March, 1954, 48 deal with classical network-theoretic problems, while 54 are concerned with « systems » problems and 16 fall into the miscellaneous category. Topics selected for the special issues of the Transactions (viz., Servomechanisms, March, 1954; Nonlinear Filters, December, 1954; Time-Varying Systems, January 1955; Signal Theory, December, 1956) also reflect this trend.

In the field of classical network theory, much of the research activity was concentrated around the following problems : (1) synthesis of two-terminal networks, (2) synthesis of two-terminal-pair networks (reciprocal and non-reciprocal), (3) realization of filter characteristics, (4) synthesis of active networks, (5) approximation in the time and frequency domains, (6) application of scattering matrices to the analysis and synthesis of n-terminal-pair networks.

Outside the domain of classical network theory, the following problems have attracted considerable attention : (1) programming of digital computers for practical network design, (2) optimization and alignment of networks by experimental techniques, (3) analysis and synthesis of discrete systems and sequential circuits, (4) synthesis of reliable networks from unreliable components, (5) analysis of time-varying and nonlinear systems, (6) analysis of systems with discrete time parameter, (7) analysis of large-scale systems.

The following list of representative papers covers only the developments made in the United States, and excludes reports on work conducted elsewhere which have appeared in U. S. publications.

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3. S. Okada. — Algebraic and Topological Foundations of Network Synthesis. *Proc. P.I.B. Symposium on Net. Syn.*, Vol. 5, pp. 283-321, 1955.
4. J. K. Percus. — Matrix Analysis of Oriented Graphs with Irreducible Feedback Loops. *I.R.E. Trans. C. T.*, Vol. CT-2, pp. 117-127, June, 1955.

2. — *Synthesis of Two-Terminal Networks*

1. F. M. Reza. — Conversion of a Brune Cycle With an Ideal Transformer into a Cycle Without an Ideal Transformer. *J. Math. and Phys.*, Vol. 33, pp. 194-198, July 1954.
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8. H. M. Lucal. — Synthesis of Three-Terminal RC Networks. *I.R.E. Trans. C. T.*, Vol. CT-2, pp. 308-316, Dec. 1955.

9. D. Helman. — Tchebycheff Approximations for Amplitude and Delay with Rational Functions. *Proc. P.I.B. Symposium on Net. Syn.*, Vol. 5, pp. 385-401, 1955.

10. E. A. Guillemin. — A New Approach to the Problem of Cascade Synthesis. *I.R.E. Trans. C. T.*, Vol. CT-2, pp. 347-355, Dec. 1955.

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N° 261. — National Committee Report on Antennas and Waveguides (Sub-Commission VI.3)

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Summary

Recent developments in some of the more active areas of antenna and diffraction theory are summarized. Although concerned primarily with U.S.A. activity, some reference is made to the literature of other countries where closely allied work is in progress. Fields included in this survey

are broad-band antennas, wide-angle microwave optics, antennas for ionospheric scatter propagation, traveling wave antennas, slot radiators, diffraction and scattering theory.

Recent work in broad-band antennas has been concerned mainly with trying to hold *both* radiation pattern and impedance independent of frequency. The problem has been approached successfully through development of that class of antenna shapes which depend on angles only. The equiangular spiral is a simple example.

In microwave optics the requirements for wide-angle scanning of antenna beams have been met largely by using new light-weight, low-loss dielectrics to construct suitable lenses such as a pherical Luneberg lens. Using the geodesic analog of the Luneberg lens in one plane, a scan of 40 beamwidths without aberrations has been obtained.

The very high gain required for antennas suitable for VHF ionospheric scatter propagation has been obtained through use of long horizontal rhombics and, more recently, by corner reflector antennas driven by collinear arrays of dipoles. The latter antennas have the important advantage for this application of much lower side lobe level.

Traveling wave antennas have received much attention in recent years because of their inherent adaptability to flush-mounted applications. Among the forms considered are corrugated surfaces and single or double dielectric-clad surfaces. The launching problem has been studied rather intensively and recent interest has been shown in the synthesis and scanning aspects for slow-wave structures. Progress has continued in the exploitation of fast-wave systems, with major advances centering on the launching problem and the polarization problem. Strip lines are taking an important place as feeding systems for traveling wave antennas.

Recent years have been marked by considerable research activity on flush-mounted microwave antennas. Such antennas often take the form of slots or apertures in the metallic surfaces of aircraft. The radiation pattern of the slot radiator depends upon the shape of the metallic surface in which it is cut, and for complicated shapes resort is made to experiment. However certain simple geometric shapes have been treated mathematically. These shapes include the circular cylinder, half-plane, wedge, sphere, elliptic cylinder, oblate and prolate spheroid, and cones. Various combinations of these shapes on which work also has been done are the semi-circular boss on a flat ground plane, the cylindrically tipped wedge, and the spherically tipped cone.

The problem of radiation from apertures in a metallic surface is closely related to the reciprocal problem of calculating the currents excited on the surface by an incoming wave. As direct consequence of the reciprocity theorem there is an intimate connection between slot radiators, diffraction and scattering. The result is that the extensive body of knowledge classed as diffraction and scattering must be considered as an integral part of antenna theory. During the past three years there has been a very considerable effort in obtaining new exact solutions, several new approximate solutions,

and a better physical understanding of the mechanisms involved in scattering. All of the geometric shapes mentioned above have received attention, and much experimental work has also been done. For the future it can be expected that this intensive effort will continue with emphasis on the asymptotic approaches of Kline and Keller, the method proposed by Logan, and Fock's method of obtaining asymptotic results based on local analysis.

Broad Band Antennas

The recent work on broad band antennas has been mainly concerned with trying to hold the radiation pattern independent of frequency as well as the input impedance. The pattern problem is much more complex and more difficult than the impedance problem and consequently most of the effort has been put on the pattern problem. A successful approach has been developed by considering antenna shapes which depend on angles only. The infinite biconical antenna is a familiar example. There is however a wide variety of these shapes which is represented by the formula $r = F(\theta)e^{a\emptyset}$ where $r\theta$ and $\emptyset$ are the usual spherical coordinates, a is a constant and $F(\theta)$ an arbitrary function of θ. Thus the cross section of one of these surfaces on a cone $\theta =$ constant is given by $r = Ae^{a\emptyset}$ which is the polar equation for an equiangular spiral.

All such antennas extend to infinity. The key problem is therefore to determine whether the pattern of a finite portion of such an antenna converges to the pattern of the infinite structure as the frequency is increased. For the biconical antenna, which is represented by $a = \infty$, it is common experience that measured patterns show no sign of this convergence. Measurements have recently been made using shapes characterized by finite values of a and the remarkable result is that most of them show this convergence with practically no doubt. In effect the current distribution remains constant with respect to wavelength and roughly concentrated in an aperture of the order of a wavelength in diameter (the effective aperture can be controlled to a useful degree by choice of the shape). Thus the pattern (and also the impedance) of such antennas is practically independent of frequency for all frequencies greater than a certain value.

Equally remarkable results have been obtained with plane structures whose shape is defined by $\emptyset =$ periodic function

of $ln\gamma$. Thus, if p is the period of $ln\gamma$ the infinite antenna is essentially the same to any two wavelengths whose ratio is exp p. Here there is the additional problem of choosing p small enough so that the variation over one period is insignificant. It turns out that this can be done quite easily in practice. For a wide range of such antenna shapes it has been found that the performance of the finite structure is practically independent of frequency above a certain point.

Wide Angle Microwave Optics

Since the last session of U.R.S.I., requirements for wide angle scanning of antenna beams have given further impetus to the investigation of wide angle microwave optics.

Although most of the recent work has been with lenses, some attention has also been given to improvement of the toroidal reflector. Along this line, it has been shown that the elliptical torus produces a more nearly plane phase front than does the parabolic torus and for very large apertures will produce a narrower beam.

In the field of microwave lenses, attention has been directed anew toward dielectric lenses. This has come abougt largely because of new developments in methods of producing lightweight, low loss dielectric materials. Lenses have been designed for wide angle applications by designing an exact two-point corrected cylindrical lens and then rotating a section of the cylindrical lens about the axis of symmetry of the section. Although lenses designed in this way will, of course, exhibit astigmatism, experimental results have been quite good for scan angles of from 7 to 14 beamwidths (depending upon f/d ratios).

Improved techniques in dielectrics, mentioned above, have also made it possible to fabricate spherical Luneberg lenses applicable to most microwave frequencies. This has given new impetus to both experimental and theoretical study of this lens. In addition to consideration of the spherical dielectric lens, some activity has continued with the geodesic analog of the Luneberg lens in one plane. Using the geodesic analog, a completely operating radar scanner, scanning over almost 40 beamwidths without aberrations, was developed and described.

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Antennas for VHF Ionospheric Scatter Communication

An important characteristic of propagation via ionospheric scatter is the relatively high loss sustained upon reflection from the ionospheric layers. Depending on the frequency and the length of the path, it may range from 70 to over 100 decibels above the free space loss. For this reason it is necessary to employ high transmitter powers and high-gain antennas for both the transmission and reception. The first antennas employed for this application were horizontal rhombic antennas employing very long, 25 to 50 wavelength, leg lengths. These are still useful, particularly for experimental purposes. They are likewise employed in some operational communication paths. Because of certain drawbacks such as the large area occupied by the antenna, the relatively high level of side and back-radiation, and other disadvantages, there has been a trend to replace the rhombic antennas by more compact structures having a much lower level of secondary lobe radiation. Corner-reflector antennas driven by collinear arrays of dipoles have been installed at many terminals. The majority of existing corner-reflector antennas have the dimensions of five wavelengths in widths, three wavelengths vertical aperture, and employ a sixty-degree aperture angle. The driven element consists of eight or more half-wave dipoles.

Because of the current high sun-spot phase of the solar cycle, the most troublesome problem of the present operation is that caused by multipath propagation. The current emphasis in the

design of the antennas for VHF scatter communication continues, therefore, to be in the design of low secondary radiation antennas.

A requirement which is likely to be incorporated in future VHF ionospheric scatter antennas is that it be possible to slew the main beam of the antenna to either side of the great circle path by an angle of ten to twenty degrees. This is made desirable because evidence exists that the meteoric contribution to scattered signal may be of considerable significance. The direction of arrival of the meteors varies with time of day and the optimum orientation of antenna varies accordingly.

Slot Radiators

Research on flush-mounted microwave antennas has been extremely active in the last three or four years. In most cases, the form of these radiators are slots or narrow rectangular shaped apertures cut in metal surfaces of aircraft fuselages, wings, or stabilizers. The radiation pattern of the antenna is very much dependent on the particular shape of the surface on which it is mounted. For this reason, recourse is often made to experiment on actual aircraft or by means of models. For a more recondite approach, the body is represented by some simple geometric shape which is amenable to rigorous mathematical treatment. The usual geometric forms, listed more or less in order of increasing complexity, are : the circular cylinder, half-plane, wedge, sphere, elliptic cylinder, oblate and prolate spheroid, and cones. Various combinations of these are also possible such as the semi-circular boss on a flat ground plane, the cylindrically-tipped wedge and the spherically-tipped cone. While none of these shapes duplicate the form of modern aircraft or missiles, they do provide a model for studying the influence of such factors as the extent and curvature of the surfaces on which the slots are cut. Furthermore, the effect of sharp edges of the surfaces can be estimated from a study of the field configurations in the vicinity of the edge of the wedge or the tip of the cone.

It is the purpose of this review to summarize some of the recent basic work in this field. It should be emphasized at the outset that the radiation from slots and apertures on a metallic surface is closely related to the reciprocal problem of calculating currents excited on the body by an incoming plane wave (1). There is an

intimate connection between diffraction and scattering which, of course, is a consequence of the reciprocity theorem (2). Therefore, any literature survey of slot antennas should include papers on the aspects of diffraction theory which have a significance in the reciprocal sense.

Due to its simplicity, the circular cylinder has been the favored model. The first approach is to represent the field in terms of a Fourier series of the form $\sum_{m=0}^{\infty} A_m \cos m\emptyset$ where $\emptyset$ is the azimuthal angle, A_m is a coefficient, and m takes all integral values. A_m is a function of the circumference of the cylinder in wavelengths (i. e., $ka = 2\pi a/\lambda$ and is determined in a straightforward manner when the field distribution over the slot is prescribed). This was the approach used by Silver and Saunders (3) to obtain an exact expression for the fields exterior to a circular cylinder of infinite length for a specified distribution of tangential voltage on the cylinder. By using a saddle point technique, the infinite integral in the solution could be reduced when the observer is in the far field. Extensive numerical results and patterns for circumferential half-wave slots for $ka = 2$, 3 and 5 and various elevation angles have been presented by Wait and Kahana (4). In this case the field is, in general, plane polarized in the principal planes but elliptically polarized for other directions. Similar numerical results for both axial and circumferential slots on large cylinders have been given by Bailin (5) for $ka = 8$ and 12, and Wait and others for a range of ka up to 21 (6, 7).

The patterns of single and pairs of circumferential slots on circular cylinders have been measured at S Band by Keys (8) in a parallel plate region and they compare favorably to the calculated data (7). Patterns of stub antennas and slots on cylinders have been measured directly by Bain (9) using an antenna range and they compare very favorably with calculated patterns for ka ranging from about 3 to 21 (10).

In most of the above-mentioned work the harmonic series representation of the field is employed. This series, which involves integral order Bessel functions, becomes very poorly convergent when ka is large compared to one. Usually, something of the order of 2 ka terms is required to secure 2 % accuracy. Extending the

classical method of G. N. Watson, this slowly converging harmonic series is converted into a contour integral which can in turn, after a deformation of the path of integration, be expressed as a new series. Individual terms are the residues of the poles encircled by the deformed contour. For this reason, such a representation is called the « residue series ». This technique has been applied to the slotted cylinder problem by Sensiper (11), and others (7, 12). A very similar approach to the reciprocal problem of diffraction by a cylinder has been outlined by Franz (13, 14) and Imai (15). Sometimes these residue terms are called creeping waves (16) as they have the characteristics of waves that creep around the cylinder with an exponential attenuation.

The residue series representation for the pattern of a slotted cylinder antenna is highly convergent in the direction away from the slot (i. e., deep in the shadow). On the other hand, the field in the forward direction (i. e., the illuminated region) can be obtained by geometrical optics (17). Difficulty occurs in the transition region near the classical light-shadow boundary. Some slight improvement can be made by considering higher order geometrical-optics terms (12). It can be shown from the harmonic series representation, however, that the field along this boundary is almost independent of ka, and hence a calculated point on the « light-shadow » boundary is always available (6). It is then possible to interpolate between the geometrical-optics and the residue series representation. The nature of the field in this transition region has been studied experimentally at Harvard (18) by examining the currents excited on a circular cylinder by an incident plane wave. They obtained surprisingly good agreement with the approximate theory of Fock (19).

The mutual impedance of the slots on circular cylinders is fundamentally more difficult to compute than the patterns because the saddle point technique of integration cannot be utilized. However, if the slots are axial and infinite in length, it is possible to compute the coupling between these by either a harmonic series (20) or a residue series representation (21). Also, it is possible to obtain the radiation conductance of finite slots on a cylinder by a Poynting vector integration of the far field (22, 23, 34). A mathematical justification for this procedure has been presented by Northover (25).

The general mutual impedance between slots of finite length on a circular cylinder, however, has yet to be expressed in a form suitable for computation.

A general analysis has been carried out for an arbitrary slot on an elliptic cylinder (26). Extensive numerical results were carried out for the limiting case (27) when the minor axis is zero (i. e., a ribbon). The current distribution on the ribbon has been evaluated for a range of widths (28). Patterns and conductances for infinitesimal slots on elliptic cylinders with a finite minor axis have been published by Wong (24, 29).

The methods for treating slots on spheres are very similar to the corresponding cylinder problems. Using a harmonic series representation, the patterns of zonal slots with uniform excitation have been calculated by Karr (30) for various polar locations of the annular slot. When the slot has a non-uniform excitation, the formalism becomes more complicated since there is no longer azimuthal symmetry (31). Numerical results for this case are also available for a moderate range of ka values (32, 33). The application of the residue series technique to the calculation of the principal plane patterns of finite slots on a sphere for large values of ka has been reported (34), and fairly good agreement was obtained with the experimental results of Cohn (35) and Bain (9). Very recently a general analysis has been presented by Mushiake and Webster (32) for the fields produced by arbitrary slots on a sphere in terms of the harmonic series representation. They presented radiation patterns for half-wave slots in the principal planes and numerical data for the power gain.

The mutual impedance between slots on a sphere has been recently calculated by using a residue-series representation which is usable if the angular separation between the slots is not small. A new series representation (36) was developed for the case of small angular separations (i. e., small curvature). The first term of this series corresponded to the mutual impedance of the slots on a flat surface and succeeding terms contain inverse powers of ka.

The radiation from slots on wedges has received considerable attention. A general analysis was presented for an arbitrary slot on a cylindrically-tipped wedge of any angle (37). Using this as a basis, numerical results have been presented for the patterns of slots parallel to the edge of a half-plane (i. e., a wedge angle

of 2π), and a right-angled wedge (38, 27). A similar treatment for radiating apertures on half-planes has been given by Tai (39) in an elegant analysis. Particular attention has been given to the case when the slot is perpendicular to and at the edge of the half-plane (27). This has been called a « notch » and it has some interesting radiation properties. The conductances of half-wave slots on circular cylinders, elliptic cylinders, wedges and half-planes have been compared to illustrate the influence of edges and curvature. (40) The more recent work on slots on wedges is concerned with developing asymptotic representations which are more suitable for calculations when the distance of the slot to the edge of the wedge is large compared to a wavelength. Schensted and Maffett (41) have shown that the geometric-optics terms can be separated out of the general solution and this step provides a new insight to the wedge problem. The difficulties associated with the asymptotic series in the transition between the illuminated and the shadow region have been overcome by Felsen (42) who applied the recent work of Oberhettinger (43, 44).

A very promising model for the treatment of radiation from slots on finite bodies of non-spherical shape is the prolate or oblate spheroid. The limiting case of the oblate spheroid of vanishing thickness (i. e., a disc) has been treated in detail by Flammer (45) for an arbitrary dipolar source. His formulas, when specialized to the case of a magnetic dipole tangential to and on the surface of the disc, are directly applicable to the radiation from a slot on a circular disc. Unfortunately, numerical results for slots on spheroids are only available for the somewhat simpler cases of azimuthal symmetry (46) with uniform excitation of annular slots on oblate spheroids and prolate spheroids (47). With the recent publication of comprehensive tables of coefficients relating to spheroidal functions (48, 49) it is expected that the formal results of Flammer for the non-symmetrical case of an arbitrary slot on a thin oblate spheroid could be used to obtain patterns. A solution for an arbitrary slot on the general spheroid (i. e., other than a disc or a sphere) does not seem to be available. It would appear that the results of Schultz (50) for the plane wave scattering of spheroid could be extended without too much trouble. Certainly, numerical results based on such a solution would be most valuable.

The very complicated problem of slots on cones has been

approached in a formal way by Bailin and Silver (51). The solution involves Legendre functions and Bessel functions of fractional order. Numerical work based on their solution is very difficult although it is justified if information concerning the effect of the cone tip on the radiation characteristics of the slot is needed. An interesting comparison of Bailin and Silver's results using a geometrical-optics approach has been made by Siegel et al. (17). The various, but equivalent, representations for the field of slots on cones have been discussed in detail by Felsen (52). This latter work should pave the way for any future numerical work on the cone problem.

Most of the above-mentioned investigations can be classified as exterior boundary value problems. That is, the distribution of the field over the slot is assumed without regard to the nature of the feed system. For electrically small slots or apertures, the actual distribution does not influence the exterior fields. Furthermore, even for half-wave slots the assumed sinusoidal distribution is very good if the slot width is small compared to the slot length. However, in general, the interior region cannot be considered separately from the exterior region since both of these determine the distribution of field over the slot. The work of Stevenson (53) in this connection is now classical. He treated the problem of matching the modes inside a rectangular wave guide through narrow resonant slots in the side walls to the region external to the guide. Recently, Oliner (54) has made some very significant extensions and he has developed formulas for the equivalent circuit of both resonant and non-resonant slots in the broad face of a rectangular guide of finite wall thickness. His experimental results show exceptionally good agreement with the theory. Some further experimental data for inclined and transverse slots in the narrow band and broad walls of a wave guide has been reported recently (55, 56).

In the theoretical work of both Stevenson and Oliner, the external region was assumed to be a half space corresponding to an infinite baffle flush with the broad wall of the slotted guide. The modification of Stevenson's formulas for resonant slots due to the finite extent and curvature of the baffle has been discussed by Wait (6, 40). Extensive work concerning the analysis of slots

in multimode wave guides has been carried out at Berkeley (57, 58, 59).

The effects associated with covering the slots with a dielectric coating such as fabric has been given some attention (6, 38, 60). A general solution is now available for the field of an arbitrary slot on a circular metallic cylinder with a concentric dielectric coating (61). Some numerical results have been obtained for *ka* values up to 8 for various dielectric constants and thicknesses of the coating (61).

The pattern calculation for arrays of slots is usually a straightforward manner. The technique is based on the principle of superposition (6, 62) wherein the total field of N slots is obtained by a complex addition. For this reason, the relative phase, as well as the amplitude of the radiated field of a single slot, is of interest. In certain beacon applications the voltage induced on pairs of slots on cylinders may be rectified before addition to obtain omnidirectional coverage (63). Some special problems associated with long arrays of slots have been discussed (64, 65, 66). The radiation from large slots (67) and U shaped slots (68) and crossed slots (69) has also been considered.

The field of slots on convex cylindrical surfaces whose curvature is slowly changing could be investigated by adapting Keller's geometrical theory of diffraction (70). In his recent work on the diffraction by a convex cylinder (71), a method is proposed for evaluating the surface currents excited by an incoming plane or cylindrical wave. The reciprocity theorem, properly applied, should yield the pattern of a slot on such a convex surface. The generalization of Keller's (71) treatment of the convex cylinder and Fock's (19) solution for the parabolic cylinder in the penumbral region has been carried out by Logan (72). He indicates that with a Table of two auxiliary functions, the patterns of slots on circular and elliptical cylinders, oblate and prolate spheroids, and other smooth curved surfaces can be readily computed to sufficient accuracy for engineering purposes. This work of Logan constitutes a major contribution to the field.

The foregoing survey is intended to provide an overall, though brief, view of the recent work on slot antennas. It is hoped that the bibliography will be a guide for others working in this field and prevent duplication in effort.

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Traveling wave Antennas

Definition. — A traveling wave antenna will be identified by a continuous or quasi-continuous non-metallic connection between the feeding structure and the antenna aperture. Thus a resonantly-spaced waveguide slot array is not considered to be a traveling wave antenna, whereas a closely-spaced waveguide slot array is so considered. Similarly, an array of dipoles fed by a coaxial

harness is not defined as a traveling wave antenna, although an array of dipoles parasitically excited by a corrugated surface is so defined.

Survey. — There has been an increased activity in this area of antenna research in the last three years, due to the inherent adaptability of such antennas to flush mounted applications. Papers have appeared which deal with corrugated and dielectric-clad surfaces, both single layer and double layer. Much attention has been given to the launching problem and recent interest has been shown in the synthesis and scanning aspects for slow-wave structures. Progress has continued in the exploitation of fast-wave systems, with major advances centering on the launching problem and on the polarization problem. Equiangular antennas are emerging as important broadband elements and new feeding systems, notably strip lines, are taking an important place as features of practical traveling wave antennas.

One of the early types of traveling wave antennas received some attention in this three year period. Panakel and Mueller (1) performed an experimental study designed to optimize the directivity of single polystyrene rod antennas. They achieved some success, but found the dimensions extremely critical. The earlier work of Attwood was extended by Hatkin (2) in a theoretical study of higher order modes in dielectric sheets. In addition to formulas connecting the modal wave lengths to dielectric properties, Hatkin presents curves of these wave lengths for the first four modes of each type. Elliott (3) unified the theory of corrugated plane surfaces, by treating the corrugated waveguide and considering corrugated parallel plates and a single corrugated surface as limiting special cases of the corrugated waveguide. He also considered the launching problem and the effect of the finiteness of a ground plane. Angulo (4) solved a difficult portion of the theoretical radiation problem for plane trapping surfaces, by considering diffraction by a semi-infinite slab. He thus provided a rigorous solution for the case of no ground plane. A paper delivered by Ehrenspeck, Gerbes, and Zucker (5) provided an interesting point of view to the explanation of why trapping surfaces radiate. The properties of two-layer dielectric surfaces were also reported. Elliott (6, 7) offered a theoretical treatment of surface waves on cylinders and spheres. He demonstrated

that such waves must leak and his theory yielded complex propagation constants. Experimental verification also showed the practical effects of this leakage through beam placement and null-filling in the radiation pattern. The properties of surface waves over an infinite ferrite ground slab were studied by Pease (8). He was able to show that for the practical case of a small ferrite layer, the fields and propagation constant could be expressed as simple closed forms and could be controlled by the magnitude of a steady magnetic field applied to the ferrite.

The launching problem for surface waves received considerable attention. Papers by Lo (9), Brick (10), Friedman and Williams (11), dealt with the classical problem of surface waves excited by a dipole placed over a trapping surface. Lo and Brick gave a general theoretical treatment, with Brick's paper supported by experimental data. Friedman and Williams were concerned with the specific problem of properly locating the dipole to produce either as pure a surface wave as possible, or to maximize the amount of energy carried by the surface wave. Kay and Zucker (12) studied the launching problem for a general source through the use of Fourier transforms. They drew an important distinction between the problems of launching a surface wave on to a transmission line and on to an antenna, reaching the conclusion that the amplitude of excitation of the surface wave is proportional to the gain of the source in free space in the complex direction that corresponds to the propagation constant of the surface wave.

The Illinois group has been studying the launching of traveling waves by means of a distributed source. Papers by Royal (13), Hodges (14), and Weeks (15) bear on this problem. Theory and experiment are in good accord. Practical significance is attached to these studies, because the distributed source is capable of producing tapered aperture distributions and thus improved radiation patterns. Royal reports excellent sidelobe levels in his experimental corroboration. Barone (16) has considered the line source equivalent of the problem treated by Lo and Brick.

The synthesis problem for surface waves has been severely hampered in a theoretical sense. This is because the method of stationary phase is not applicable to a constant velocity slow-wave. An iteration technique was attempted for slow-waves by Stephenson and Walter (17), with only limited success. An

experimental investigation by Elliott (18) concluded that two practical methods for controlling a radiation pattern of a surface wave antenna were to use a curved geometry and to taper the degree of trapping. Application of these techniques to practical antennas were reported by Plummer (19), and Butterfield (20). An experimental study of parasitic excitation of radiating elements was also undertaken by Elliott and Rodda (21). The geometric parameters were so critical that the conclusion was reached that a rigid connection between the parasites and surface wave would be necessary in any practical application. An interesting experiment was described by Ehrlich and Williams (22). They treated a radiating discontinuity in a surface wave transmission line as a four-terminal network and attempted to measure the circuit properties through the use of efficient launching and receiving horns. The high degree of accuracy required to obtain the circuit data resulted in an extremely delicate experiment, only limited success being achieved.

A significant advance in the synthesis of radiation patterns from surface waves has been made recently. The limitation of the method of stationary phase to fast-waves have been overcome by a study of *modulated* slow-waves. This problem has been studied by Zucker and Thomas (25) and by Pease (24). They were able to show that a modulated slow-wave could result in a very high endfire gain or in a beam tilted at an arbitrary angle with the surface.

Scanning of surface wave antennas is a difficult problem. (Except, of course, the case in which the entire antenna is mechanically rotated.) Two attempts at scanning have been reported. In the first of these, Ehrlich and Williams (25) described an investigation wherein they attempted to pass a constant frequency surface wave over a corrugated surface at an arbitrary angle to the corrugations. They found that the pattern deteriorated rapidly as the scan angle departed from the normal longitudinal direction. Hougardy and Hansen (26) performed the same experiment using a frequency-scanned source. The frequency change compensated for the scan angle by making the corrugations appear electrically deeper. This resulted in an acceptable pattern over an appreciable scan angle.

The considerable body of work done by the Ohio State group

on the subject of fast-wave antennas was summarized in a paper by Hines, Rumsey, and Walter (29). A theoretical method for computing complex propagation constants was presented separately by Rumsey. This paper contains an important theorem on reciprocity for traveling waves. Recently a simplified method for computing leaky propagation constants has been provided by Goldstone and Oliner (31). Their procedure employs a perturbation method which is based on the transverse resonance condition for the existence of the pertinent leaky wave. An application of Rumsey's method to the specific problem of an axially slitted cylinder was reported by Harrington (32). Stephenson and Walter (33), in a separate paper, gave further details of the Ohio State program. They reported several practical antenna designs and disclosed the development of successful discontinuity minimizers which greatly aided the launching problem. Walter (34) reported the extension of many of these ideas to a curved traveling wave slot aperture. Hines, Rumsey, and Tice (35) pointed out the need to properly define the element pattern in the design of an array. The usual method of pattern multiplication can lead to errors when scattering from the elements is appreciable.

The continuous slots reported by Ohio State were successful for transverse polarization, but contained practical difficulties in the case of longitudinal polarization. By going to a quasi-continuous aperture, the Hughes group was able to achieve comparable success with longitudinal polarization. Stegen and Reed (36) initiated this program by using closely spaced nonresonant slots at the outer conductor of a loaded coaxial transmission line. The loading was used to speed up the wave and the size of the slots were used to control the leakage. Satisfactory patterns with longitudinal polarization resulted. Elliott (37) applied this technique to rectangular waveguide and recognized that this structure was a corrugated waveguide opened to outer space. He then applied corrugated waveguide theory to this problem and was able to theoretically determine the leaky propagation constants. In a separate paper, Kelly and Elliott (38) reported the experimental verification of the theory and several practical antenna forms. Recently the Illinois group has become interested in this problem and Hyneman (39) has treated the complementary problem with excellent agreement between theory and experiment. Kelly (40)

has applied these techniques to closely spaced annular slots on cones.

Hines and Upson (41) report success with a variable polarization traveling wave antenna. Their technique uses edge slots cut in a rectangular waveguide as a line source radiating into a parallel plate transmission line. By mechanically changing the geometry they continuously varied the polarization from linear to circular. Another application of traveling wave antennas was reported by Bergman and Schultz (42). They used a circular conductor feed at one point and so terminated at the diametrically opposite point, that only a traveling wave existed on the antenna. Their experimental results were hampered by high sidelobe levels.

A unifying paper was presented by Reynolds (43) in which he pointed up the basic identity of such diverse antenna systems as the helical antenna, the dielectric antenna, the corrugated surface, and the long Yagi antenna. Also speaking in general terms, Marcuvitz (44) pointed out that leaky modes cannot comprise an orthonormal set nor can they satisfy the field requirements at infinity. However, in a restricted space region, they provide highly convergent approximations to problems in which the fundamental operation of the electromagnetic system results in a leaky wave.

The published literature on spiral antennas and their equivalents is still fragmentary. However, in 1954 Barnett and Crowley (45) pointed out the wide band possibilities of equiangular antennas whose geometries were thereby frequency-independent. In a general paper, Rumsey (46) discussed the need to investigate those antennas of this class which could be properly terminated and pointed out several practical examples. An investigation of one of these practical examples was undertaken by Duhamel and Isbell (47).

Major progress has been made in the fabrication of strip lines. This has opened up the possibility of using transmission lines of this type to feed antennas and has even resulted in the integration of the strip line and antenna aperture. Keen (48) and Frost (49) report the progress in component development and McDonough and Malech (50), Rotman and Karas (51, 52) propose many interesting applications to traveling wave antenna systems.

Assessment and Projection. — In reviewing the progress represented by the papers discussed above, several conclusions seem reasonable. Electromagnetic field solutions for fast and slow waves are now well understood for all structures of the simpler geometric shapes. Some progress will undoubtedly still be made in simplifications and refinements of the present theories. An excellent start has been made on the theoretical synthesis of patterns from slow-wave structures by use of the modulation concept. The exploitation of wideband antennas through the use of geometries in which angles are preserved is a new subject which will probably receive considerable emphasis in the years to come. A major breakthrough in the fabrication problem is needed and the increased use of strip line techniques may offer a solution. It would seem from this vantage point that the activity in traveling wave antennas in the next three years will be principally characterized by experimental programs designed to improve development techniques and provide practical antennas.

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DIFFRACTION AND SCATTERING

The period from 1 July 1954 through 1 May 1957 in the United States has been marked by a considerable effort in the Diffraction and Scattering Field. This effort has consisted primarily in obtaining new exact solutions, several new approximate solutions and a better physical understanding of the mechanisms involved in scattering. Since this survey is limited to United States contributions, it is rather difficult to isolate particular efforts because many of them have been inspired by the work of individuals of other countries ; for example by Bremmer, Fock, Franz and Friedlander. Methods which had not been used during the previous three years were applied to solving boundary value problems during this period. There has also been considerably heightened interest in the experimental determination of diffraction and scattering answers.

Considerable work has been done on reformulation and obtaining new solutions. Emphasis here has been on the wedge, cylinder, sphere, dielectric coated sphere, cone, paraboloid, special angled corners, parabolic cylinder, prolate spheroid, and many apertures and wedges with cylindrically tipped edges.

Asymptotic results have been obtained for the cylinder, sphere, paraboloid, and for apertures, wedges and cones. These asymptotic evaluations have in many cases resulted from methods outlined during the last period. Keller conceived the geometric diffracted ray technique. He applied this technique to cylinders of arbitrary cross section, including the parabolic cylinder and the circular cylinder as special cases (1). By the same method he solved the

arbitrary aperture problem (2), and compared his results with other asymptotic aperture methods (3). Rice (4) obtained the exact parabolic cylinder results, which he shows approach the correct limit when the cylinder approaches the half-plane of Sommerfeld, or the thick half-plane of Artmann. Rice's results can be predicted using Fock's approximation where the latter is valid. Schensted (5) used the Luneberg Kline asymptotic series to solve the paraboloid boundary value problem with the transmitter on the axis. He showed that for the perfectly conducting paraboloid the leading term of the Luneberg Kline series was, in fact, the exact far zone field. Schensted also solved the general body of revolution problem for a plane wave incident along the axis of symmetry by Luneberg Kline expansion. Felsen (6) and Siegel, Crispin and Schensted (7) solved the exact back scattering cone problem and compared the results with the asymptotic results obtained from the Kirchhoff theory. They found, for large and small cone angles, that the leading term in the cross section, when the plane wave was on the axis, was in agreement with the exact solution. Felsen showed further that for the case in which the transmitter is on the axis of symmetry and the receiver is not, Kirchhoff theory was in good agreement with the exact solution. Kirchhoff results for these shapes and many others are presented by Siegel, Alperin, Bonkowski, Crispin, Maffett, Schensted and Schensted in Reference 8. Felsen has extended the cone answer to obtain the results in a transition region and the region close to the boundary.

Oberhettinger (9, 10) has found many neat asymptotic formulations for wedge problems. Keller, Seckler and Lewis (11) have given additional terms in the asymptotic series for many simple shapes. Kline (12) has extended his asymptotic development obtaining an expansion in fractional powers of the wavelength. Schensted (13) obtains an asymptotic solution for a plane obstacle by neglecting higher variations in the geometrical optics approximation to the phase.

Cohen (14) applied Rumsey's reaction concept to obtain a scattering result for the dielectric cylinder. Wu (15) used a creeping wave concept and applied Riemann surface techniques to the cylinder problem. This had been suggested in a paper by Friedlander (16). Rubinow and Wu (17) succeeded in finding several

terms of an asymptotic expansion for the total scattering from cylinders and spheres. Schiff (18) generalized the Born approximation to include scattering governed by Maxwell's equations. This method is particularly useful for scattering in non-spherical regions where the index of refraction is a slowly varying function of value nearly unity. Kay and Keller (19) have obtained the Luneberg expansion of the field of a caustic. Many asymptotic solutions for the scattering of waves by gratings have been given by Twersky (20). In Reference (21), Karp and Russek obtained asymptotic results for the diffraction of a wide slit. Huang, Kodis and Levine (22) have made many important numerical computations comparing theoretical and experimental aperture diffraction results. Hirshfield and Zieman (23) made measurements of microwave diffraction from long slits in a thin conducting plane.

Other Important Results

Marcuvitz (24) has extended his field representation to be applicable to leaky modes or eigenmodes. Significant results by variational theory in addition to those of Huang, Kodis and Levine mentioned above, were obtained by Kouyoumjian (25) in his treatment of a circular loop. These results are in agreement with the exact solution of Weston (26). Erdelyi and Papas (27) used a variational method to obtain solutions for an infinite strip. They used a trial function that ignored edge effects and obtained good numerical results for the entire range in wavelength. Heins (28) obtained the scattering due to a dipole field incident on a perfectly conducting half-plane. He and Silver (29) gave results which led to new insight concerning edge conditions and field representation theorems in the general theory of diffraction. However their emphasis was primarily on aperture problems. Row (30) has obtained theoretical and experimental results for two identical conducting cylinders in the resonance region.

Basic Foundations

The tensor scattering matrix for the electromagnetic scattering field has been derived by Saxon (31). An expansion theorem for electromagnetic fields was given by Wilcox (32). Wilcox also has shown that in any finite region the electromagnetic field can be

represented by Debye potentials (33). Peters and Stoker (34, 35) gave a unique decomposition of the radiation condition for application of uniqueness theorems to semi-infinite bodies. A new method for obtaining scattering solutions for bodies that can be mapped conformally on a circle has been given by Garabedian (36). Siegel, Schultz, Gere and Sleator (37) obtained numerical results for nose-on back scattering by a 10 : 1 prolate spheroid. A digital computer was used to sum the exact series solution.

Experimental Work

A great deal of experimental work has been done which has not yet appeared in journal articles. Among the important unpublished results is the experimental work of Brick and Wetzel at Harvard on circular and elliptic cylinders. Measurements on spIeroids and finite cones have been made by Honda at the University of California (Berkeley), Broadside measurements of spheroids and cylinders were undertaken by Rabinowitz at Johns Hopkins University. The University of Texas has performed many experiments on wedges and corners.

The United States has a large body of theoretical and experimental data collected but not journalized in the past three years. These data can usually be obtained by writing or visiting Air Force Cambridge Research Center, Cornell Aeronautical Laboratory, Inc., Stanford Research Institute, Harvard University, Johns Hopkins University, The Ohio State University, Radiation Incorporated, University of California (Berkeley), University of Illinois, University of Texas, and University of Michigan.

Epilogue

The fact that so much information exists in report form which is not yet in journal form makes it quite easy to predict what the next three years should bring to journal literature in the diffraction and scattering field in the United States. A good deal of emphasis is being placed on the results of Fock. His method of obtaining asymptotic results, based on local analysis, will probably be used to derive new results. Further emphasis will be placed on geometric diffracted rays by the Keller approach. A method proposed by Logan which replaces the divergence condition by a condition

on the field at infinity, applying an idea due to Müller, will undoubtedly lead to new representations for exact solutions. The effect of creeping waves which are focussed towards an effective point singularity, then reflected and defocussed, will also be the subject of analysis during the next three years. Weston's method of obtaining exact solutions for Maxwell's equations for bodies which are not contour surfaces of separable coordinate systems will undoubtedly be the subject of considerable analysis. It is expected that scattering in the Rayleigh region will receive more attention than it has in the past three years. The work of Stevenson, Mushiake and Tai probably will lead to new theories and new methods of solving Rayleigh problems.

The asymptotic approaches used by Kline and Keller will undoubtedly receive considerable attention and will be used to solve many more problems than previously.

The work of Fock will undoubtedly receive additional attention from people in the antenna field. It is expected that radiation theorists will place more emphasis on scattering results than they have in the past. The reaction concept will undoubtedly be analyzed and used more as it becomes better understood.

The large variety of publications in the diffraction and scattering field has required that a certain number of these be left out. Rough surface work and scattering from colloidal particles and collections of spheres have been deliberately omitted as being more properly the subject of other Commissions.

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Report of the Chairman of the Commission

to the Plenary Opening Session

Mr. President, Ladies and Gentlemen

If my report should strike you as being unduly brief, please keep in mind that Commission VI has always been concerned with compression of bandwidth and conservation of channel capacity.

The program of Commission VI for this General Assembly is set up in the pattern of its three Sub-Commissions : Information and Communication Theory, Circuit Theory, and Electromagnetic Theory as it applies to Radiating Systems.

The first technical session, which will be held this afternoon, will feature the work of a Sub-Committee on Microwave Optics and Information Theory. Discussion will center on the interrelation between the space-harmonic and time-harmonic spectra of an antenna system. This is a subject which involves all of the Sub-Commissions, bringing together field theory and circuit theory and information theory.

In its own particular province the Sub-Commission on Information Theory under the chairmanship of Dr. van der Pol will consider problems of coding and transmission through cascaded systems. It will also deal with the special problems in communication theory referred to U.R.S.I. by the C.C.I.R.

The Sub-Commission on Circuit Theory under the chairmanship of Prof. Tellegen will discuss broad aspects of the field with the objective of determining the most significant areas for future research.

Sub-Commission VI-3 under the chairmanship of Prof. Sinclair has arranged three sessions, one each on Scattering and Diffraction, the Transition from Maxwell's Equations to Low and High Frequency Limits, and Surface Waves, respectively. The discussions will be initiated by invited papers given by Prof. Siegel of the

University of Michigan, Prof. Chu of the Massachusetts Institute of Technology, and Prof. Barlow of University College, University of London, respectively.

Mention may have been made by Dr. Laffineur of the joint session of Commissions V and VI on the topic of large antennas. The discussion on Microwave Optics and Information Theory which we shall hold this afternoon has bearing on this subject and will serve as a preparation of our Commission for the joint session. We hope to contribute also to other aspects of the antenna problem and we shall certainly find many ideas for the future program of the Commission in the joint session.

In closing I wish to express my thanks to the chairmen of the Sub-Commissions and to Mr. Loeb, Vice-Chairman of the Commission, for their generous and invaluable assistance in preparing the program for this General Assembly. Thank you for your attention.

Minutes of the Sessions of the Commission [1]

SESSION I : ADMINISTRATIVE MEETING OF OFFICIAL MEMBERS

(*Chairman* : Prof. S. SILVER)

Friday, August 23, 2.00 p. m.

The Chairman opened the meeting with a report on the actions of the Executive Committee which were referred to the Commissions for their consideration in the meeting of the Coordinating Committee held earlier in the day. The particular points were as follows :

(*a*) The Executive Committee decided to dissolve all Sub-Commissions currently in existence and requests that Commissions review their needs for Sub-Commissions and make corresponding recommendations. Sub-Commissions shall no longer have a permanent status but must be reviewed at each General Assembly.

(*b*) The Commission is requested to make recommendations as to Chairmen of Sub-Commissions. Comments were solicited also on procedures for making appointments. One suggestion that has been offered is that the Chairman of a Commission shall make his recommendations to the Board of U.R.S.I. and that the Board shall be authorized to appoint the Sub-Commission Chairman. This provides for the cases when Sub-Commission chairmen are appointed in the period between General Assemblies, when it would delay the activity too long by requiring an exchange of correspondence between all members of the Executive Committee.

(*c*) The Executive Committee recommends that in choosing Chairmen of Sub-Commissions the prime consideration be given to effectiveness of the Chairman rather than to maintaining geographical or national distribution among the officers.

(*d*) The Executive Committee urges that Commissions elect two secretaries, one French speaking, one English speaking and that they be permitted to serve no more than two terms.

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[1] These minutes are compiled from notes taken by Messrs. LOEB, STUMPERS, TWERSKY, BLACHMAN and GREEN.

(*e*) The Executive Committee feels that more symposia should be sponsored, particularly such that cut across lines of Commissions. The views of the Commission are requested and also suggestions of topics.

It was generally agreed upon by the Commission that the nature of the subject matter falling within the province of Commission VI created organizational needs that were somewhat different from those of other Commissions, that the three Sub-Commissions which were created in The Hague seemed to be meeting those needs and had been quite effective during the past three years. There was unanimous agreement that we should continue the present Sub-Commission structure for the following three years.

The Commission voted in favor of a motion offered by Prof. JORDAN that the Chairman recommend to the Board the re-election of the present Chairmen of the Sub-Commissions.

With respect to the Sub-Committee on Microwave Optics and Information Theory it was the sense of the Commission that it should not be reconstituted at the present time.

There was a general feeling of doubt as to the need for secretaries for the Commission in view of the organization into Sub-Commissions. There are already five officers - Chairman, Vice-Chairman, and three Sub-Commission Chairman - which seems to be adequate to deal with the business of the Commission. It was decided to let the decision on this matter rest until the end of the meeting.

There was considerable discussion on the matter of symposia : It appears to be reasonable that in a Commission such as VI each Sub-Commission should sponsor a symposium in its own field. The objection was raised that such a number of symposia is too much for U.R.S.I. to support and that the Executive Committee would not approve. The problem actually arises only with respect to getting financial support from U.R.S.I. for a symposium.

SESSION II : OPENING SESSION FOR COMMISSION VI

(*Chairmen* : Prof. S. SILVER, Prof. Balth. VAN DER POL)

Monday, August 26, 2.00 p. m.

The first part of the meeting dealt with administrative and procedural matters. Prof. SILVER reviewed the discussions that

took place at the administrative sessions of Commission VI on Friday, August 23. Because several of the official members had not been able to attend that meeting the voting on Sub-Commissions and officers was called for at this session. The Commission voted in favor of the continuation of the three Sub-Commissions for the next three year period and recommended the election of the Chairmen named in the minutes of the administrative session. It was also recommended to the Executive Committee that Prof. SILVER and Mr. J. LOEB be re-elected Chairman and Vice-Chairman, respectively, of the Commission for the next three years.

Prof. SILVER turned the chair over to Prof. VAN DER POL for the technical phases of the session dealing with the report of the Microwave Optics Sub-Committee and the Communication Theory monograph project.

Dr. SPENCER, Chairman of the Sub-Committee on Microwave Optics and Information Theory, reviewed the activities of the Sub-Committee during the past three years and summarized briefly the report of the Committee which had been distributed to Commission VI. Parts of the report were to have been presented in some greater detail but of these only the paper by Prof. A. BLANC-LAPIERRE was given at this session and the others deferred to the joint session with Commission IV.

Prof. BLANC-LAPIERRE in a paper entitled « Contribution to the Study of Optical Noise Comparison with Noise in Radio-Electricity» discussed spatial variations in image formation arising from granularity and drew a parallel between random functions expressing the image fuzziness and the random functions designated as « noise » in electric signal formation and transmission. He commented on the work of various authors on the statistical analysis of various models of optical granularity and experimental measurements of these statistical properties.

Dr. V. TWERSKY raised the question as to how information theory as such enters into the treatment of the problem and in particular as to whether the information theory aspect applies to calculating the limitation of resolution caused by the « noise ». Prof. VAN DER POL commented that Prof. BLANC-LAPIERRE was seeking to characterize the « noise » of the photographic plate by a set of statistical parameters such as the density of grains, distribution law of their diameter, etc.

Prof. SILVER expressed the opinion that much of the work in the application of information theory to optics was inclined to exaggerate the formal analogy between space-dependent optical phenomena and time-dependent electricel phenomena and that Commission VI should pay more attention to the cases when the phenomena become interlinked as happens when an optical system is a component in a communication system. Mr. LOEB noted that the analogy between the « noise » aspects of optical images and the « noise » in communication systems is but a restricted example of information theory in a multi-dimensional space.

Prof. VAN DER POL brought up the problems and topics referred to Commission VI of U.R.S.I. by the C.C.I.R . A Sub-Committee of Sub-Commission VI-1 was set up to deal with C.C.I.R. Study Program 86-Communication Theory- and the Question 133 concerning :

1. « the relation between permissible delay and residual uncertainty and its dependence on bandwidth utilization ;

2. the improvement practically possible in existing systems with regard to the transmission of information, in particular for those systems where a « go » and « return » channel are available.

The Sub-Committee was constituted as follows :

J. LOCHARD (France).

V. E. SIFOROV (U. S. S. R.).

F. L. H. STUMPERS (Netherlands).

H. C. A. VAN DUUREN (Netherlands).

Regarding the other items that the C.C.I.R. referred to Commission VI, Prof. SILVER commented as follows :

Report 46. — « Temporal variations of ground-wave field strength» may come under consideration of Commission VI in connection with surface waves but at the present is not clearly within the field of the Commission.

Question 125. — « The usable sensitivity of radio receivers in the presence of quasi-impulsive interference » is related to the topic which was submitted to Commission VI by Commission IV in the Hague at the 11th General Assembly. The membership of Commission VI does not seem to have among it circuit and communication engineers who can deal with the question effectively.

Such people seem to be more closely affiliated in interest with Commission IV and perhaps the most effective procedure would be to ask Commission IV to take the problem under consideration. A note was drawn up for transmittal to Mr. RATCLIFFE, Chairman of Commission IV, asking him to take on Question 125.

Question 137. — « Measurement of field strength in the neighborhood of obstacles. » This topic falls under the general heading of the material to be considered in the session on Scattering and Diffraction and a program for dealing with the question will be formulated later.

Mr. J. LOEB gave a résumé of the monograph project started in The Hague in 1954 in order to show how communication and information theory are utilized in a practical design problem. He gave an outline of the program which he proposed to cover in the monograph and referred to interim reports and contributions by N. BLACHMAN and R. SILVERMAN. He then summarized his paper « Cascaded Binary Channels » in which he treated the effect of cascading fixed, memoryless binary channels, pointing out that the probability matrix describing the result is the product of the probability matrices describing the component channels.

It was agreed that the work should be continued through the next three year period and the following agreed to participate with Mr. LOEB in the project.

N. BLACHMAN (U. S. A.).
J. LOCHARD (France).
V. E. SIFOROV (U. S. S. R.).
F. H. L. STUMPERS (Netherlands).
H. C. A. VAN DUUREN (Netherlands).

The Committee arranged to meet and discuss plans and suggestions for the program of the project.

SESSION III : CIRCUIT THEORY

(*Chairman* : Prof. B. D. H. TELLEGEN)

Wednesday, August 28, 9.30 a. m.

The session developed around a paper « Survey of Circuit Theory » prepared by Prof. TELLEGEN. In his opening remarks Prof.

TELLEGEN recalled the recommendations made in The Hague in 1954 that general problems rather than specific topics should be discussed at the General Assembly. He had written this paper to provide a basis for discussion out of which he hoped it would become clear in which directions the Sub-Commission should go.

His first topic was that of defining the area of circuit theory, particularly in the sense that it falls within the province of a Commission of U.R.S.I. He proposed that the subject matter be designated as that of networks, composed of black boxes, characterized by relations containing neither space nor temperature coordinates. A lively discussion ensued immediately.

Prof. ZADEH found it difficult to agree to a rigid prescription of the boundaries of the field and felt that switching circuits, discrete machines and similar components fall properly into the circuit field and have direct bearing on radio and communications. Prof. TELLEGEN wished to make a distinction between the cases of networks in which the information considerations are of primary importance and those in which energy transfer are primary, feeling that the former were more properly the concern of the Sub-Commission on Information Theory.

Prof. VAN DER POL and Dr. TRAUTMAN brought up the ideas that other coordinates than voltage and current could be taken as the network variables, e. g. : electric and magnetic flux. TRAUTMAN'S suggestion implied a generalization to other than electromagnetic systems. In reply to that TELLEGEN expressed the opinion that electrical networks should be the primary subject matter and other networks could then be treated by analogy.

Dr. WEINBERG proposed that an infinite number of elements be excluded so that the analytical domain would be restricted to the domain of rational functions. Dr. SCHELKUNOFF felt that that represented an undue restriction of the field. He could see no objection to allowing space coordinates to enter into the problem as parameters so that a section of waveguide can be considered properly as a circuit element.

Dr. STUMPERS pointed out that the exclusion of temperature coordinates implies the exclusion of noise from the theory. Noise could come into consideration if temperature were taken to be one of the parameters of the system. It was agreed that variables

might be a more suitable word than coordinates in setting up the definition, that length and temperature may be regarded as parameters. Prof. TELLEGEN was reluctant to enlarge the domain, for the purposes of Sub-Commission VI-2, to include noise theory.

The discussion turned again to Prof. ZADEH's opinion that systems such as the multi input-output data systems of Moore would become increasingly important in engineering and that the Sub-Commission in Circuit Theory should give attention to such developments. Prof. VAN DER POL remarked on the growth of the field and that perhaps several definitions are needed to delineate it.

Prof. TAKAHASI objected to the concept of a finite number of elements in the network and called attention to important work on approximation by infinite number of elements. This brought up again the matter of a distributed constant system and space coordinates. Prof. SILVER remarked that he could not see why transcendental functions should be excluded since they must come up anyway in non-linear problems. It was his view that the essence of circuit theory as contrasted with say field theory is that attention in circuit theory is directed to dynamical variables associated with terminals. A section of transmission line or waveguide is an admissible element when the relation that are primary are those between the variables at the terminals.

There was further discussion on analogies and more abstract definitions. Prof. TELLEGEN felt that such questions are too far removed from the problems of interest and that it is essential to make some definition of the boundaries of the field.

ZADEH, TRAUTMAN, REZA, INOSE and WEINBERG decided to form a group to explore the possibilities of drawing a wider definition for the field of circuit theory.

Prof. TELLEGEN next led the discussion to the task of circuit theory (Secs. 2.1 to 2.6 in his paper).

Dr. TRAUTMAN said that space considerations would come into a discussion of topology and later HOK suggested that continuous space coordinates should be excluded rather than discrete ones (referring again to the definition of the field); allowance must be made for the introduction of space coordinates in the enumeration of ports.

Dr. STUMPERS called attention to another analysis problem : If the physical box is given, what measurements should be made to characterize it ? They are well known for the case of a linear network but not so in the case of a nonlinear network. Theoretical work remains to be done on this matter.

Dr. WEINBERG thought that Prof. TELLEGEN connected necessary and sufficient conditions with construction. He referred to a thesis by Cederbaum wherein necessary and sufficient conditions are given without a proof of construction. It was WEINBERG's point that necessary and sufficient conditions do not mean actually prescribing the elements of the network. He commented also that the split into time and frequency domain synthesis is artificial, that Cerrillo, for example, worked with conditions in both domains at the same time.

Introducing the third part of his paper Prof. TELLEGEN said he was well aware of its incompleteness and asked for contributions.

Dr. WEINBERG referred to the work of LUCAL on the synthesis of R. C. three-poles and remarked that one of the conditions given in that work was not really necessary. In a forthcoming publication in the *Trans. of the Professional Group on Circuit Theory*, SLEPIAN and WEINBERG will come close to necessary and sufficient conditions.

WEINBERG thought that even the problem of the real matrix and the resistive n-ports without transformer is still open. BURINGTON's dominant matrix condition did not seem right to him, but in this Prof. TELLEGEN stated that necessary and sufficient conditions for n-poles are known.

For n-ports the situation is different. Necessary and sufficient conditions are known for 2 and 3 ports, but the general case is stil open FOSTER and CEDERBAUM have worked on it.

TELLEGEN now showed that the concepts of port, order and rank for low numbers automatically give the well known elements R, L, C, transformer and gyrator This seems a less arbitrary approach than idealization from physical elements

One can extend the notion to non-linear elements, that are piece-wise-linear (possibly an infinite number) : One linear part gives the normal elements. Two linear parts give the ideal rectifier.

WEINBERG drew attention to the effect of special configurations.

If one restricts himself, the synthesis problems become easier. He referred to ladder networks and Tschebysheff and Butterworth polynomials. He referred to Indjoujian's work connected to ellyptic functions, and finally stressed the synthesis implications of Kirchhoff's rules, too much neglected. The Fialkow-Gerst conditions can be derived from them.

Prof. VAN DER POL motioned a vote of thanks for the able leadership of the chairman which was heartily approved.

SESSION IV :

JOINT SESSION OF COMMISSIONS V AND VI ON LARGE ANTENNAS

(*Chairmen* : Prof. A. C. B. LOVELL, Dr. R. C. SPENCER)

Wednesday, August 28, 2.00 p. m.

Thursday, August 29, 11.00 a. m.

The two Commissions joined to discuss those problems of large antennas that are particularly significant in the field of radio-astronomy. The part of the session on Wednesday afternoon was chaired by Prof. LOVELL, that on Thursday morning was presided over by Dr. SPENCER.

Wednesday afternoon was devoted to a presentation of types of antenna installations in the United States, Great Britain, Australia, France, Germany, the Netherlands, Russia, Japan. The emphasis was decidedly on cylindrical and circular paraboloidal reflectors and on mechanical problems associated with the large reflector. Various performance characteristics were quoted but there was not sufficient time to make a careful review and in particular to compare the various systems presented.

Dr. BRACEWELL made some comments on tolerances and his feeling that certain tolerances were being emphasized unduly much and others not sufficiently. He summarized briefly some studies which he made on the performance of reflectors and his theoretical analysis which indicated that a highly important parameter is the mean square deviation from the ideal surface.

Dr. VAN ATTA made some remarks on the difficulties attendant on construction and use of a steerable reflector of very large size and urged that more attention be paid to two-dimensional reflec-

tors. He compared some of the advantages and disadvantages of reflectors and arrays.

The meeting was resumed on Thursday at the indicated time. Prof. SILVER opened the discussion with a summary of the problems that were apparent from the presentations made the previous afternoon. He felt that some of the performance characteristics that were claimed were not consistent with theoretical considerations. He delineated the following points on which he hoped discussion would take place :

(1) *f/D ratio.* — Criteria for choice of a given *f/D* ; importance of spillover and effect of ground reflections on the effective antenna temperature.

(2) *Aperture blocking.* — The extent to which the mechanical structure for holding the feed, together with the feed, destroys the pattern ; limitation of antenna size conditioned by aperture blocking.

(3) *Mesh size.* — What is the upper frequency limit ? What is the tolerable percentage of transmission as is determined by ground return ?

(4) *Tolerances.* — What are the actual problems ?

(5) *Reflectors vs Arrays.* — A careful comparison of potential performance and of their realizability.

(6) *Optimum aperture.* — Comparison of gain as a function of area between cases of :

(*a*) completely coherent radiation,

(*b*) partially coherent radiation,

(*c*) totally incoherent radiation.

Dr. PAWSEY added that he should like to hear discussion emphasizing the problems of high resolution and gain and as to what can be done to feed large parabolas and suppress sidelobes. He wished to get opinions on parabolas and arrays in respect to resolution problems.

Dr. FINDLAY discussed the U. S. A. National Observatory program for a paraboloidal reflector having a diameter of 140 feet. He stated that he is intolerant of theories on average of irregula-

rities, that he was more concerned with the actual answer with a real dish. He said that the proposed antenna at Greenbank would be required to have a surface accurate to 0.25″ and that model studies would be made at X-band with the various mechanical stresses expected in the case of the large antenna being simulated.

Prof. LOVELL made some remarks on the Jodrell Bank installation and stated that their choice of a focus-in-the-face reflector was based on considerations of screening the feed. He objected to arrays on the grounds that they are frequency sensitive.

Discussion developed on aperture blocking and the effect on gain and sidelobes. Prof. SILVER suggested that another study be made of the ring source feed and ring focus reflector as a possible way to reduce aperture blocking and meeting some mechanical problems.

Dr. SPENCER turned the discussion next to the work of the Sub-Committee on Microwave Optics which he had directed during the past three years. Dr. WOLF presented material from his part of the report. He discussed briefly coherence and showed that there is a correlation function for radiation that propagates as a wave function.

Mr. ZUCKER referred to work done at the Air Force Cambridge Research Center on optimum f/D ratio in the presence of 1st, 2nd and 3rd order spherical aberration in the case of random detail. He also commented on discrete and continuous arrays and the effect of periodicity in structure on the far zone pattern.

Dr. SEEGERS remarked that the spillover effect is important in the continuous radiation when it is desired to measure small signals. He felt that it was important to outline the basic problems and that the matter of large antennas be approached from the standpoint of what it is desired to observe and how the antennas are to be used; limit on the flexibility of the equipments then follow as well as a guide as to how to build them.

SESSION V : PROPERTIES OF TRANSMISSION CHANNELS

(*Chairman* : Prof. Balth. VAN DER POL)

Thursday, August 29, 9.30 a. m.

Dr. F. L. H. M. STUMPERS presented an analysis of a number of different binary codes that have been proposed and used in tele-

printer service where a feedback path is available for announcing to the transmitter that an error has occurred in transmission, so that the symbol can be repeated. Dr. H. C. A. VAN DUUREN pointed out that there are situations in a physical communication link where the simple model of independent errors in successive signal elements breaks down.

Prof. H. TAKAHASI read a paper by S. MUROGA « On the channel capacity of a noisy channel which is expressible by corresponding two multi-state diagrams ». In this study the channel consists of two linear graphs such as were used by SHANNON to describe a Markov information source, plus a matrix of transition probabilities connecting the state changes in both graphs. The channel capacity is computed for a channel with intersymbol constraints defined in this way. The two graphs represent opposite ends of the channel. Prof. ZADEH raised the point that the usual definition of channel capacity requires that not only the probabilities of various state transitions in the first linear graph be variable, but also the topological structure of this graph.

Prof. TAKAHASI also read a paper by Prof. MINE on « Transformation of probability distributions and its application to compander systems ». In this paper, expressions for self and conditional entropy of signals with given amplitude density distributions are employed to treat the information rate in a channel composed of two successive and complementary amplitude distortions with noise added between them. The channel capacity and optimum forms of nonlinearities are derived. Discussion centered around the question of the time delay involved in companding (the nonlinear operation).

Dr. BLACHMAN presented three studies of communication systems in which the channel disturbance is controllable. Such studies are intended to provide lower bounds for information rates when the exact statistics of the interference are unknown. The interference is chosen so as to minimize the rate of information flow to the receiver. The first of these papers « On the effect of interference : prevarication versus redundancy », treats the role of the redundancy of the language in overcoming the errors due to interference. In his second paper « Communication as a Game », the author analyzed the conflict between the communicator and the interference by describing a simple two-person, zero-sum game-theoretic

model in which the pay-off is the information rate. Time permitted only a partial presentation of the third paper « A remark on the amount of interference a communication system can tolerate », which asks what is the optimum (worst) form of interference if the signals are like white gaussian noise, as proposed by SHANNON, and the interference may depend on the exact forms of the signals.

Dr. ILYIN presented a discussion of a two-velocity scanning system used to allow facsimile transmission of black-and-white printed material with a smaller bandwidh than for uniform scanning (« A method of electronic photo-telegraphy with high efficiency of information transmission »). The slow scan is used only in the vicinity of changes in brightness. An operating system has been built which exhibits a five-to-one reduction in total scanning time over the usual uniform-velocity method for the same bandwidth and for which there is only a slight deterioration in picture quality.

Dr. P. E. GREEN presented a paper co-authored by Dr. R. PRICE entitled « An anti-multipath communications system (Rake) », which discussed the principles, design, and performance of a probability-computing receiver designed to operate with wide-band transmitted signal in such a fashion as to minimize the deleterious effects of random multipath and additive noise. A measurement of the multipath characteristic is required, and the discussion involved the question of the averaging time of this measurement.

A paper by Prof. D. A. BELL entitled « The negative entropy of recorded information » was commented on briefly by Dr. R. E. BURGESS. This paper points out that an information loss due to thermodynamic effects is inevitable in the storage elements themselves that form a part of the information handling-systems treated by information theory.

SESSION VI : PROBLEMS IN ELECTROMAGNETIC THEORY

(*Chairman* : Prof. E. C. JORDAN)

Thursday, August 29, 2.00 p. m.

The session, according to the original plan for Commission VI, was to be devoted to the topic of the Transition from Maxwell's Equations to the Low Frequency Limit of Circuit Theory and the High Frequency Limit of Geometrical Optics. However, the

He asserted that a generalization is possible for smooth convex obstacle.

Prof. KLINE remarked on the Luneberg theory and his subsequent development thereof in which asymptotic developments for the fields are obtained in the form :

$$E(\omega) = A(\omega) \sum_{0}^{\infty} \frac{1}{(j\omega)^n} E_n(x, y, z)$$

where $A(\omega)$ is independent of x, y, z and can have a range of dependencies on ω_0. In certain cases $A(\omega)$ generates functional powers.

Dr. SCHELKUNOFF gave a short exposition on approximation to Maxwell's equations based on the generalized telegraphist equations. For two and three wire lines and waveguides one gets an exact set of infinite number of ordinary differential equations.

Dr. WAINSTEIN gave a summary of his paper in which some problems with regard to group velocity and group delay are discussed. This also generated a number of comments on the historical aspect of the subject. Prof. GRIVET and MANNEBACK and others as well referred to earlier work especially that of Brillouin (Congrês Inter. d'Electricité, 1932).

Prof. FRIEDMAN showed that one can get the results by saddle-point approximation to the integral for a wave packet.

Prof. CHU began his presentation on electrodynamics and the formulation of the field equations and force laws in media on the basis of microscopic electrodynamics. He proceeded by setting up two alternate schemes for Maxwell's equations, one an $\vec{E}$, $\vec{H}$ scheme and set up « Poynting theorems » according to each scheme. The $\vec{E}$, $\vec{B}$ scheme led him to the concepts of surface energy sources and to a formulation that did not transform properly under a relativistic transformation.

The discussion that was generated by just Prof. CHU's opening remarks was so extensive and the opinions expressed were so varied that Prof. CHU could not get on very far with his presentation before it was time to adjourn. The discussion was continued the following day (11.00 a. m.) and Prof. CHU presented some further aspects of his work. Unfortunately there was not enough time to see the properties of the formulation under a Lorentz transformation which would have been the key to the entire

matter. The hope was expressed by all present that there would be further discussions and exchange of views on the subject.

Session VII : Spectral Analysis

(*Chairman* : Prof. Balth. van der Pol)

Friday, August 30, 9.30 a. m.

The third session on information theory dealt generally with spectral analysis. It began with a paper by Prof. V. E. Siforov left over from the second session « On the capacity of channels with random parameter fluctuations ». His formulation provides a lower bound for the channel capacity in cases where there are one or more signal paths from transmitter to receiver, with randomly-varying amplitude and/or delay. In the presence of slow Rayleigh fading of a single path, a maximum deterioration in channel capacity of 17 per cent was found. Dr. Feinstein stated that with Rayleigh fading a smaller deterioration could be obtained by transmitting pulses instead of white gaussian signals when the signal-to-noise ratio is high. With more rapid variations of one or more parameters, Siforov found that for each channel model there exists a threshold in fluctuation rate below which the channel capacity is infinite, provided that there is no other form of interference present. Above the threshold, the capacity decreases monotonically. In response to a question by Mr. J. Loeb, the author explained that the threshold point depends on the channel model and, for a given channel model, is proportional to the signal bandwidth. Dr. Green conjectured that the curve asymptotically approaches a positive value as the fluctuation rate increases and that it is already close to the asymptotic value for a fluctuation rate equal to the signal bandwidth. Prof. Kotelnikov pointed out that for high fluctuation rates, one must consider that the bandwidth of the received signal is greater than that of the transmitted signal.

Prof. A. Blanc-Lapierre presented a study made two and a half years ago by himself and B. Picinbono « On the notion of instantaneous power spectra ». He gave five conditions that any method of defining instantaneous spectrum should fulfill, and he examined three proposed methods of defining instantaneous power spectrum (one by C. H. Page, an analog of this, and a method due

to Ville). The conclusion was that none of these three formulations satisfied all five conditions. Dr. STUMPERS suggested consideration of an approximate measuring scheme whereby a number of adjacently-tuned filters are used, each followed by a square-law detector.

Dr. J. C. LOCHARD presented a summary of a paper by DEMAN entitled « Instantaneous spectra and signal analysis — applications to problems of telecommunications ». The author uses the theory of analytical signals (as formulated by Gabor) to define a transmitted signal, and additive noise, and a filtering operation at the receiver. He also analyzes the number of distinguishable signals in the presence of noise.

Next Dr. STUMPERS briefly presented a paper by G. F. GOURIET « A note on the definition of group delay », pointing out that amplitude slope and delay time are the real and imaginary parts of a complex function of frequency describing a transfer characteristic and that they are thus each other's Hilbert transforms

Dr. STUMPERS then presented a preliminary report by as tudy group consisting of himself as chairman, Dr. J. C. LOCHARD, Prof. V. E. SIFOROV, and Dr. P. E. GREEN, who was replaced on his departure from Boulder (31 August) by Dr. N. M. BLACHMAN. This study group was set up to deal with questions touching information theory put to U.R.S.I. by the C.C.I.R. (Warsaw meeting, 1956) (1).

The study group directed its attention to Question 133, Study Program 86, and Report 38. In all three cases the members of the group felt it to be impossible to give final answers at the present time. In the report, however, attention was drawn to recent research pertinent to the questions so as to indicate the direction from which useful results can be expected. In regard to Question 133, reference was made to work on the relationship of code length to channel capacity and error rate, to work on the utility of a feedback communication channel for correcting errors, and to the value of modes of detection other than binary for detecting binary signals. Dr. STUMPERS noted that the feedback path does not

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(1) The study group met again on Monday afternoon, Sept. 2, to prepare the final version of the report which Dr. STUMPERS was to present at the closing session of Commission VI.

increase the channel capacity but that it simplifies the coding problem. He also suggested error rate as a more useful criterion than channel capacity. In regard to Study Program 86, which deals with power, time, and spectrum conservation, reference was made to work on combating the effects of fading, multipath, scattering, and high noise levels by the use of communication theory. The closing section of Report 38 was cited as a useful review of the work done on the problem of determining the type of emission producing minimum interference.

Finally, Mr. LOCHARD discussed Report No. 38, which had been presented to the VIIIth Plenary Assembly of the C.C.I.R. in Warsaw in 1956, and which was published in the proceedings of that conference. This report deals with the spectra of random signals, the reduction of out of band radiation, and the reduction of bandwidth. Mention was made of the inequality which the duration-bandwidth product must satisfy. In the discussion period, R. A. SILVERMAN stated that the usual inequality fails when applied to narrow-band signals whose spectral densities do not vanish at zero frequency, and, in particular, with a gaussian spectrum truncated at zero frequency, he has obtained a duration-bandwidth product little larger than 1/4. Here « bandwidth » refers to the rms bandwidth.

SESSION IX : SCATTERING AND DIFFRACTION

(*Chairman* : Prof. N. MARCUVITZ)

Friday, August 30, 2.00 p. m.
Monday, September 2, 11.30 a. m.

Prof. K. M. SIEGEL gave an invited paper on « Far Field Scattering from Bodies of Revolution » which served as a keynote for the session. He treated approximate solutions for scattering cross sections over the entire range of dimensions from the Rayleigh region where the dimensions are very small compared with wavelength to the Kirchhoff region where the dimensions are large compared with the wavelength. He reviewed the field at large as well as giving results which he and his co-workers had obtained. Problems to which he gave particular attention are those of back-scattering for « nose-on » aspect of ellipsoids of revolutions, cones, and ogives.

In the Rayleigh region, he stated, the backscattering cross section must be of the form :

$$\sigma = \frac{4}{\pi} k^4 V^2 f$$

where $k = 2\pi/\lambda$, V = volume of the body and f is a dimensionless factor depending upon the shape and aspect. He discussed the shape factor of several configurations.

He considered the use of geometrical optics and the Kirchhoff methods of physical optics for the cases when the dimensions are large compared with the wavelength and showed how the methods can give good results for infinite wedges and cones. When, however, there is a sharp edge that makes a major contribution, the technique breaks down and special consideration must be given to the edge. By way of illustration he dealt with the case of a right circular cone of finite height and the case of an electromagnetic wave incident onto the tip aspect along the axis of symmetry. The region of the edge at the base can be considered locally as a section of a wedge and by using the Sommerfeld solution for an infinite wedge he obtained an approximation to the current distribution in the local neighborhood. The complete edge then appeared as a ring singularity.

The backscattering cross-section as a function of wavelength has an oscillatory character. The « resonance region » is that where the Rayleigh value exceeds the geometrical optics result, and includes all maxima greater than or equal to the first. For the cone, there is essentially a ring resonance arising from the edge of the base. The results of WESTON and KOUYOUMJIAN for the ring, may be used to connect the Rayleigh and short-wave backscattering curves for the cone.

If a body has a radius of curvature small compared to wavelength, it gives a point type discontinuity which reflects energy back to the source. The front tip of an ellipsoid contributes little, while the rear tip has a reflection coefficient of about 1. PETERS and BELKINA treat thin bodies by regarding them as traveling wave antennas. PETERS measured voltage reflection coefficients on ogives to be 0.7 ; for thin rods he found about 1/3 ; these agree with calculations.

The subsequent papers and discussion dealt with topics introduced by Prof. SIEGEL.

Dr. WESTON discussed vector wave functions in torroidal coordinates, and applied them to treat scattering by a circular loop. Although the Helmholtz equation is non-separable in torroidal coordinates, one can approximate the scattered field to an error of the order of $\frac{r^2}{a}$ where r = wire radius, a = loop radius. To obtain higher approximations, one uses a combination of the vector wave functions such that the components tangential to the torus are orthogonal to a higher approximation. He showed slides of the coordinates, the wave functions solutions, far field forms, and graphs of backscattering for angles 0, 30°, 60°, 90°, and wire radius $r/a = .01$, $.005$, and $.008$. The position of the resonance in the backscattering is essentially independent of r for $r \ll \lambda$.

Prof. HALLEN commented that the thin torus antenna could be solved exactly and simply as compared to other antennas, and referred to Rayleigh's (1914) results on the free oscillation problem. In the range $r/\lambda \to 0$, results can be obtained in cartesian coordinates. Free oscillations of a torus involve exactly sinusoidal currents.

Prof. J. B. KELLER pointed out that since the torroidal solutions are not orthogonal on the boundary. Weston's procedure is not exact.

Prof. S. SILVER asked Prof. SIEGEL for a criterion for the number of maxima in the resonance region, and SIEGEL then discussed the form of $\frac{\sigma}{\pi(b^4/a^2)}$ for the ellipsoid of revolution for « nose-on » incidence of both an acoustic wave and an electromagnetic wave.

Prof. K. MORITA discussed the current distribution on a rectangular plate and its effective radar area. Computations were based on using the Sommerfeld half-plane results for the currents near the edges, and neglecting interactions as well as corner effects. Currents were also measured directly and compared with theory.

Prof. KELLER commented on SIEGEL's discussion of successive maxima for ellipsoids and their behavior with increasing wavelength. The resonance is due primarily to interference between the ray from the tip of the ellipsoid (1) and the ones that « crept » around the back (2); the creeping rays (2) have a caustic on the axis and therefore the effects are large. The geometrical value

of the contribution by ray (1) is constant and (2) decreases with λ; therefore expect that the maxima should decrease with λ. However, there is a correction to (1) of the order λ, whose sign depends on the boundary conditions. In acoustics, the maxima increase for a rigid surface, and decrease for a free surface.

Prof. KELLER discussed the ray theory for finite cone. The tip contribution is of order λ (spherical wave) and the base edge contribution is of order $\sqrt{\lambda}$ (cylindrical wave). The base wave has a toroidal wave front with caustics both on the edge and axis. Because of focusing, the base wave is multiplied by $\frac{1}{\sqrt{\lambda}}$, and therefore this contribution is independent of λ. There is interference between the rays singly reflected from the edge, and those doubly reflected (i. e. which « creep » along the back of the cone's base). At the edge, use diffraction coefficient from SOMMERFELD'S or MACDONALD'S results on wedge.

Dr. TWERSKY pointed out that if one followed SIEGEL and used the ring result for the resonance region of the cone, then WESTON'S current loop resonance seemed to give a different resonance value of *ka* than that obtained on the basis of KELLER'S picture of interference between the single and double reflected edge waves. In KELLER'S picture, the second rays travelled and additional distance of the diameter of the base, and also picked up an additional SOMMERFELD phase factor at the second edge. In SIEGEL'S picture the significant distance is the circumference of the base; the resonance occurring at $ka = 1$. SIEGEL'S picture based the resonance on the « single scattering » behavior of the edge, and KELLER'S on the interference of the first and second orders of scattering by the edge.

Next, Dr. H. J. NEUGEBAUER discussed a HUYGEN'S principle procedure for treating thick screens capped by semi-cylinders, and compared the results with experiments. The intent was to develop a simple procedure for treating obstacle gain phenomena. The procedure was based on « four rays » : (1) the direct wave to the semi-infinite « aperture » above the obstacle; (2) the wave specularly reflected from the obstacle to the aperture; (3) a direct wave from the aperture to the field point; an (4) a wave from the aperture specularly reflected from the obstacle to the field point. The reflected waves were multiplied by the appropriate geometrical

divergence factors. In addition, as suggested by Fock's work, a « reflection coefficient » of 0.7 was used for vertical polarization, and the geometrical value, -1, for horizontal. Agreement with experiments (40° beam widths, and $kd \approx 250$, with d = distance from horns to obstacle) was better than that obtained from RICE's and ARTMANN's results.

L. A. WAINSTEIN discussed work in Moscow going back 12-13 years to FOCK and LEONTOVICH. For edged bodies, one uses SOMMERFELD half-plane currents for the edges, and multiple scattering procedure for inter-actions ; the corner is still an open problem. A series of papers by Upintself (to appear this year in J. Tech. Phy.) treat the strip, disk and finite cylinder. If the body has no edges, and the FOCK currents are used, then the radiated field must be consistent with approximation for currents. Work of Russians on cylinder and sphere have been translated by Morris FRIEDMAN ; more detailed treatment will appear in Radio-Tech. and Elec. The work can be used for discussions of KELLER's diffracted rays ; i. e., KIRCHHOFF integrals and stationary phase leads to diffracted rays from glints on bodies and edges. In addition to the existing approaches to wave theory, i. e., geometrical optics, physical optics, and the mathematical theory of diffraction, he suggested a fourth, « the physical theory of diffraction ». This last would include SCHWARTZSCHILD's treatment of the slit by using SOMMERFELD's half plane result, the recent work on thin antennas by HALLEN and his pupils, and other problems which are difficult to treat mathematically with the required rigor.

Prof. SILVER discussed experimental results at BERKELEY on scattering by curved strips of infinite length (studies in a parallel plate region giving a two-dimensional field problem). The purpose was to find to what extent the first approximation for the surface current (i. e., the geometrical value $k_0 = 2M \times H_0$) accounted for the radiation field, and whether edge currents were needed. For normal incidence, it was found that no edge currents were required for practical purposes ; the finite sheet of geometrical current sufficed. For other angles of incidence, the geometrical current predicted the correct positions of the maxima and minima but not their amplitudes, i. e., the geometrical currents are not adequate for the amplitudes if appreciable phase distortion exists on the aperture.

KELLER discussed SILVER's results on the basis of ray theory ; here the SOMMERFELD half plane currents would be used to get edge diffracted rays. At normal incidence the diffraction coefficients of the two edges are equal, but at other angles they differ in amplitude but not in phase. SILVER used « KIRCHHOFF edge currents » instead of « SOMMERFELD edge currents » ; since the phases of the two sets are the same, both give correct position for the extreme. However, only the second, which takes amplitude differences at edges into account, will give correct amplitudes of field.

KELLER referred to WAINSTEIN's fourth approach and said the extension had been made by LUNEBERG who sought a systematic rigorous procedure for obtaining asymptotic solutions of the wave equations for simple bodies. LUNEBERG found the leading term, and KLINE obtained higher terms for the ordinary rays. Then KELLER introduced diffracted rays.

SIEGEL made several comments on the remarks of SILVER and KELLER on the location of the extrema. Then SILVER distinguished the various kinds of resonances that were of interest : amplitude extrema as function of angle ; or of body parameter ; or of aspect ; or of λ.

Dr. TWERSKY discussed the role of the single-body resonance phenomena in many body scattering problems. In the resonance region, the usual single scattering approximations (which neglect coupling effects), or perturbation techniques based on them, were in general invalid. This was illustrated by stating relatively rigorous closed form results for planer and volume, periodic and random distributions of scatterers, and applying them to lossless resonant dipoles. The closed forms gave physically meaningful results at resonance, whereas the single scattered approximations were either singular or unrealistic.

SESSION X : CIRCUIT THEORY

(*Chairman* : Prof. B. D. H. TELLEGEN)

Monday, September 3, 9.30 a. m.

The session was devoted mainly to contributed papers. Prof. TAKAHASI presented the paper by TAKAHASI and GOTO on the parametron, a non-linear amplifier that is suitable for computers.

It is built up from non-linear ferrite coils with low losses but not necessarily square magnetisation loops.

Prof. MORITA introduced HIRAYAMA's paper on « Theory of a Negative Impedance Convertor » in which he showed how a transistor with $\alpha = 2$ can be made into a negative impedance converter.

Mr. ROBIN gave a brief report on a paper by Sideriades on « Topological Methods Applied to Electronics » (Méthode topologiques appliquées à l'Electronique). Non-linearities of the first and second order are treated with applications to multivibrators, flip-flop systems, relaxation and saw-tooth oscillators. Further details may be found in J. de Phys. et le Radium (1956) 18, 304. L'Onde électrique, January 1956.

Prof. ZADEH gave a resumé of Prof. REZA's paper « A Multiplication Theorem for Positive Real Functions ». The paper is based on the mapping of the right half plane on a circle.

If

$$\frac{1 - Z_1}{1 + Z_1} \cdot \frac{1 - Z_2}{1 + Z_2} = \frac{1 - Z}{1 + Z}$$

and Z_1 and Z_2 are positive real functions, then Z is also positive real. The result can be extended to scattering matrices. It is doubtful whether all positive real functions can be built up this way.

Mr. MARIÉ gave a survey of his forthcoming book « La Théorie des Biquadriondes et ses Applications » to be published by GAUTHIER-VILLARS in which he treats 4-pole waveguides in which there are eight progressive ways (4 entering, 4 outgoing). Symmetry considerations are used to simplify the field problems. The theory is applied to semireflecting mirrors, directional couplers, magic T's, interferometers, non-reciprocal filters and related topics.

Prof. ZADEH discussed a definition of circuit theory suggested by the study group (INOSE, REZA, TRAUTMAN, WEINBERG, and ZADEH) :

« Circuit Theory is the theory of networks or « black boxes » which are characterized by relations between voltages, currents or other variables at their terminals and which are, in general, abstractions of physical components of electrical systems. »

Although this definition is just slightly different from that given

by Prof. TELLEGEN (see Session III) the authors feel that it would leave room for introduction of switching circuits and even of probabilistic calculations. The Chairman did not favor the wider definition, and Dr. STUMPERS pointed out that many problems of the last category had been treated previously under the heading of Information Theory. Many others felt that the problems do fall properly under Circuit Theory. As an example reliability considerations were also mentioned.

With regard to the program for the next three year period and the following General Assembly, Mr. LOEB suggested the topic of Equivalent Networks. Dr. WEINBERG proposed that a survey be made of all that is known about *necessary* and *sufficient conditions* in network theory, or necessary or sufficient conditions alone where both are not present. He also proposed a study of explicit formulae for element values in synthesis problems, comparison between networks with and without transformers, and, in a wider sens, synthesis of sequential circuits.

SESSION XI : SURFACE WAVES

(*Chairman* : Dr. J. R. WAIT)

Monday, September 3, 2.00 p. m.

The technical program opened with a survey of the field of surface waves by Prof. H. M. BARLOW, University College, University of London. He reviewed a wide variety of problems to show the interrelationship between propagation along the interface between two media, propagation over a corrugated metal surface, guided wave propagation along dielectric-coated conductors, to mention a few. The paper was not only a review of the field at large but also was a summary of researches carried on by Prof. BARLOW and his colleagues at the University of London.

The subject of surface waves has been surrounded by controversy since 1909 when SOMMERFELD published his paper in Annalen der Physik. The discussions that developed during the sessions indicated that the situation will remain so for some years to come.

Prof. Balth. VAN DER POL presented his treatment of the dipole over the earth (flat earth), the excitation of the dipole being the step (Heaviside) function. He developed the solution by opera-

tional techniques and for the case of a dipole at the surface of the earth and field points on the surface was able to show explicitly several different wave terms of which one can be considered a Zenneck wave. He showed also some very interesting features of the field away from the surface of the earth.

Dr. SCHELKUNOFF made some pertinent remarks about the location of the pules and the branch point in the Sommerfeld integral. He also commented on varieties of surface waves that can be identified. Further comments were made by Prof. N. MARCUVITZ ; he suggested that the SOMMERFELD problem be buried once and for all.

The general consensus was that while the classical problem has now been solved adequately, the extension to other types of surface waves which have very different features has led to many misconceptions. There was much debate on terminology and Dr. WAIT stressed the need for unifying both the approach to the general subject and the terminology of the field. The outgrowth of this discussion was the creation of a working party to prepare a review of the entire subject for the next General Assembly. The members appointed to the working party by Professor Sinclair are :

Prof. H. M. BARLOW (England),
Dr. H. BREMMER (Netherlands),
Prof. A. L. CULLEN (England),
Prof. N. MARCUVITZ (U. S. A.),
Dr. L. A. WAINSTEIN (U. S. S. R.),
Dr. J. R. WAIT (U. S. A.).

The radiation from surface waves was also considered. Dr. J. P. SIMON disclosed some very recent advances in the design of surface wave antennas. The novelty of the technique lies in launching surface waves on a structure along which the phase velocity is modulated. Under certain conditions it is possible to produce very narrow beam widths with low side lobes using physically realizable structures. An example is the « cigar antenna» consisting of a dielectric rod with concentric metal discs of varying diameters. Mr. F. J. ZUCKER made some remarks about the general theory of tapered surface wave antennas, especially on the concept that modulated surface waves can be analyzed in terms

of spatial side bands in analogy to amplitude modulation in the time domain.

Other papers that were on the agenda were as follows :

Y. MORIWAKI and T. KAWAMURA, *A Corrugated Plane Reflector*,

M. A. MILLER and V. I. TALANOV, *Surface Electromagnetic Waves*,

H. KIKUCHI, *On the Transition from a Ground Return Circuit to a Surface Waveguide*,

R. GAJEWSKI, *Pulse Propagation in Wave Guides*,

K. MORITA, *Pseudo-electromagnetic Retarding Medium Using Loop Coils.*

Unfortunately time was too limited to allow due justice to be given to the material and discussions were very much limited. This points up the difficulties in arranging and carrying through a technical program and the need for consideration of procedures.

SESSION XII : CLOSING SESSION OF COMMISSION VI

(*Chairman* : Prof. S. SILVER)

Wednesday, September 5, 9.30 a. m.

The Chairman expressed the sense of loss by the untimely death of Prof. Marcel BAYARD of the French National Committee and the Commission voted a resolution that a suitable memorial be published in the Proceedings of the General Assembly.

In accordance with the views expressed by the Executive Committee that each Commission should have a French and an English speaking secretary, the Chairman called for nominations for secretaries. Mr. P. MARIÉ was nominated for the post of French secretary and Prof. H. MEINKE was nominated for the post of English secretary. The nominations were closed and the candidates named were elected by unanimous vote of the Commission.

Brief summaries of the activities of the Sub-Commissions were presented by Dr. STUMPERS (acting for Prof. VAN DER POL), Prof. TELLEGEN and Prof. SINCLAIR. Sub-Commissions VI-1 and Sub-Commission VI-2 offered no formal recommendations for the program of the following three year period but will continue to explore the views and interests of people in the field by correspondence. Sub-Commission VI-1 will continue the work of the study

group set up on the C.C.I.R. question (see Appendix B) and also the monograph project (Appendix A). Sub-Commission VI-3 submitted a set of recommendations. The list of resolutions and recommendations appear later in these minutes.

The discussion turned next to a consideration of C.C.I.R. problems. The Chairman referred to the study group on surface waves (see Session XI) the C.C.I.R. report No. 46 on temporal variations of ground-wave field strength with the recommendation that the study group consider the surface wave aspects of the problem together with their other subjects.

The Chairman received a reply from Mr. RATCLIFFE concerning Question 125 (II) on the usable sensitivity of radio receivers in the presence of quasi-impulsive interference to the effect that the subject is basically in the province of Commission VI and that Commission VI should assume responsibility for the matter. Cooperation of Commission IV in every possible way was assured by Mr. RATCLIFFE. In recognition of the need for a special type of communications specialist in the membership of Commission VI in order to contribute to the C.C.I.R. project, the Commission submitted its Resolution No. 2. Dr. STUMPERS agreed to take on prime responsibility for the work and requested that the Chairman try to enlist the aid of Dr. WATTS of the National Bureau of Standards and Mr. CHAPIN of the Federal Communications Commission.

Question 137 (V) regarding the measurement of field strength in the neighborhood of obstacles can be answered only by gathering together data on scattering and information on experimental techniques. This is a project that will take some time and a working party was set up to carry on the study. The membership consists of :

Prof. J. KELLER,
Dr. H. NEUGEBAUER,
Dr. L. G. A. ROBIN,
Prof. K. M. SIEGEL,
Prof. S. SILVER.

The Chairman commented on the problems of organizing the technical sessions and on problems encountered during the General Assembly. He called for expressions of opinions on the programs

and suggestions for future General Assemblies. The opinions were as varied as they were numerous and finally it was possible to draw a majority point of view which is expressed in the form of Item No. 4 under Resolutions and Recommendations.

The Chairman closed the session with an expression of thanks to the delegates, Chairmen of the sessions, and the Sub-Commission Chairmen for their contributions to the organization and conduct of the General Assembly and to the work of the Commission.

The Chairman had received word that, because of other commitments and duties, one of the Chairman of the Sub-Commissions may find it necessary to resign from the position subsequent to the close of the General Assembly. In order to minimize the delay in providing the Sub-Commission with a new Chairman that would be occasioned by the required correspondence with all official members concerning the nomination of a new Chairman, Professor SILVER requested that the Commission vote him authority to make a direct nomination to the Board on behalf of the Commission. The request was approved by unanimous vote of the official members in attendance at the closing session.

APPENDIX A

Minutes of Monograph Group

(*Chairman* : Mr. J. LOEB)

Mr. LOEB's monograph group met twice, on Monday afternoon 2 September and on Wednesday afternoon 4 September The purpose of the monograph is to demonstrate to practical communication engineers the usefulness of communication theory in the design of a complete communication system, but it is also expected to describe important new results of interest to communication theoreticians. The particular system toward which attention may be directed is FSK teletype using cascaded channels subject to fading. It is expected that the monograph will first appear as an U.R.S.I. document, but subsequent commercial publication is possible. It is intended that each chapter of the monograph should be self-contained but the editor, Mr. LOEB, is to write an introduction and suggest necessary alterations to make the work fit together smoothly. A preface by Prof. Balth. VAN DER POL

would be in order, insomuch as it is through his suggestion that this project is being undertaken.

SILVERMAN is to discuss the discrete memoryless channel, justifying the notion of capacity by discussing the recent work of SHANNON, and ELIAS, including their finite-block-length coding theory. He also proposed to discuss instantaneous rate, MCMILLAN'S equipartition theorem for independent, MARKOV, and stationary sources, the coding of information in binary digits, and the effect of cascading binary channels.

ZADEH is to discuss the discrete channel with memory by using a MARKOV model of a channel with transition probabilities depending on the input. He hopes to be able to determine when such a system has a finite memory and to determine the probability structure of the output given that of the input.

BLACHMAN will discuss the continuous nature of the binary channel and the effect of interference. His chapter may discuss entropy and its coordinate dependence, sampling theorems, information rate, communication as a game, channel capacity, communication-system capacity, the application to the power- and bandwidth-limited case, redundancy, and the tolerable error rate.

STUMPERS and VAN DUUREN will discuss coding and other means for combating noise and interference, LOCHARD will discuss adjacent channel interference, and SIFOROV will discuss time-varying channels and the parameters that characterize such channels, such as the relation-ship of probability of error to speed. SIFOROV will analyze several types of channels, including both uni-beam and multi-beam models.

LOEB suggested that each of the chapters should be about twenty double-spaced typewritten pages long and a first draft should be sent to him within a year.

APPENDIX B

Report of U.R.S.I. Commission VI on C.C.I.R. Questions Regarding Communication Theory

(Prepared by a Study Group of Commission VI-1)

The study group has discussed Question 133, Study Programme 86, and Report 38. In all three cases the members of the group felt it to be impossible to give final answers. It may be

useful, however, to draw attention to recent research pertinent to the questions and to give some general ideas on the direction in which we expect useful results.

Question 133. From the considerations it appears that this question affects the rather limited case of additive white gaussian noise, with limited bandwidth signals and no fading or other non-additive disturbance. Part 1 of the question has been the subject of research by SHANNON, BARNARD, ELIAS, and SIFOROV. In this work no general expression for the relationship between error rate, channel capacity, and code length (or delay) has yet been given, although useful results on presumably near-optimum situations have been obtained.

In connection with Part 2, recent work indicates that the availability of a feedback path does not increase the channel capacity when the noise in the feedback channel is incoherent with that in the feed-forward channel, even if the former is zero. On the other hand the problem of coding and decoding is reduced considerably by the use of such a path. Studies on the effect of feedback in communication channels have been made by CHANG, SHANNON, ELIAS, and by BISHOP and BUCHANAN. In treating existing systems or simple modifications of them, error rate rather than channel capacity seems to be a more immediately useful concept.

An important recent development is the work of WOZENCRAFT who has devised a coding scheme with the following property : The number of code-book entries M grows with increasing code length n as n^i (where i is of the order of 2 or 3) rather than 2^n which was to be expected on the basis of previous studies of long codes. The slow rate of increase appears to bring the use of very long coding and decoding operations much closer to the point of practical feasibility.

A part from work on alternate codes and studies of the use of feedback channels, it appears that great promise is also to be seen in better methods of reception, for example the use of a ternary receiver decision : ZERO, ONE and DON'T KNOW. Some results on this are already available in the work of BLOOM, CHANG, *et al.*, and by COHEN and JUNG. Other papers are mentioned in the references.

Study Programme 86. — In the years elapsed since this was proposed at Geneva in 1951, the considerations of this study pro-

gramme remain valid. A comprehensive study comparing different modulation systems from the point of view of communication theory was recently given by KNUDTZON, who studied a channel with additive interference only.

Among the phenomena peculiar to radio propagation indicated under 1 there are fading, multipath, scattering, and possibly other disturbances. Some work has been done on applying communication theory to such situations. PRICE has studied the channel capacity of stationary multipath and SIFOROV has dealt with time-varying multipath. Pertinent work of FEINSTEIN, ENOMOTO and ROSENBLATT-ROTH should be mentioned. PRICE and GREEN discuss a coding and reception system especially designed to combat multipath and additive noise disturbances. It is known that further studies are in progress and perhaps a useful review of work on such more complicated types of channels can be given in the future.

With reference to the note added to the document referring to communication in high noise levels, we suppose many results will be available in different countries. We refer to the paper by de JAGER and GREEFKES.

As to the question of methods best suited for practical application we cannot at present make a useful comment. It is in principle possible to take into account the cost and complexity of equipment factors in designing a system, but we do not know of researches in this direction.

To promote practical application of the results of information theory, attempts should be made to derive relations between the mathematical concepts of the theory and the practical concepts familiar to engineers, that are in some cases more accessible to direct measurement. A more detailed outline of such a work and a table of related concept was given in the Annex of Geneva Question 49 of C.C.I.R.

Report 38. — The Committee has individually examined this report although not in enough detail to offer a complete opinion on every point raised. It is our opinion that especially the closing section of the report constitutes a useful review of the work done to the present on this problem. Some papers of interest that appeared since, are those by LAEMMEL and GUREVICH.

The optimum pulse shape for minimum interference depends on the definitions of delay, duration and bandwidth and on the constraints of the problem. An interesting unsolved problem is : to find among the class of physically possible signals (no discontinuities, exponential decrease) with given time duration (appropriately defined), those with the largest part of the energy in the frequency band $0 - f_0$.

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Report for Commission VI

to the Closing Plenary Session, September 5, 1957

Mr. President, Ladies and Gentlemen :

The sessions of Commission VI — Radio Waves and Circuits — were marked by lively and instructive discussion. The activity was in fact so great that we found it necessary to expand our original program of seven sessions to ten.

Sub-Commission VI-1 held three sessions, the main topics of which were Information Theory and Optics, Spectral Analysis, and Transmission Channels. In the field of Information Theory and Optics, Commission VI had for some time a Sub-Committee under the chairmanship of Dr. SPENCER to study the interrelation between information and communication theory and the theory of aperture type antennas and to correlate the physical principles and mathematical techniques of the two respective fields. The Sub-Committee has been discontinued but its report has indicated the need for further researches in this area and we are accordingly calling this to the attention of U.R.S.I. in our recommendations for future work.

At the General Assembly in The Hague the Commission set up a group to prepare a monograph on communication systems as an example of the practical utilization of information and communication theory. The developments to date on the monograph were discussed by Sub-Commission VI-1 and plans were made for continuation of that project. Mr. LOEB will continue as Chairman of the working group.

The program of Sub-Commission VI-2 was initiated by a paper by Prof. TELLEGEN directed toward defining the area of circuit theory and the outstanding research problems in the field. This engendered considerable discussion that made clear that we shall in the near future have to consider sequential and digital systems in communications networks. It is hoped to explore further

during the following three year period the points of view expressed in this meeting and the exchange of ideas may crystallize into a topic for the next General Assembly.

The main topics of the program of Sub-Commission VI-3 were Scattering and Diffraction, the Transition from Maxwell's Equations to the Low Frequency Limit of Circuit Theory and the High Frequency Limit of Geometrical Optics, Fundamentals of Electrodynamics, and Surface Waves. Some of the most challenging features of the invited papers which led the programs were the examination of fundamental concepts. The paper by Prof. CHU on his interpretation of the electromagnetic field vectors and the formulation of the forces on material media in electromagnetic fields was especially provocative and showed that there is a need for a critical re-examination of the relation between classical microscopic electrodynamics and macroscopic electrodynamics. The results may be significant in the interpretation of the phenomena dealt with by the other Commissions of U.R.S.I.

The discussions on scattering and diffraction showed that there is much to be done yet in understanding the scattering of waves by bodies whose dimensions are comparable with the wavelength, that is, when strong resonance phenomena can be observed in the scattering process. It is also important to consider scattering when the field is other than time-harmonic. The importance of the problems has been recognized by one of our recommendations for future work.

The study of surface waves is of importance to the antenna field and to the general theory of propagation over the Earth. The discussions at the present General Assembly brought to light differences in meaning as to what constitutes a surface wave as well as a number of important and fundamental problems. A group has been set up to follow up certain aspects of the discussions started at the Assembly and to stimulate further work in the field.

The C.C.I.R. referred four topics to Commission VI. One of them is closely related to the theory of Surface Waves and we shall look to the working group on Surface Waves to investigate the aspects of the problem that belong properly to Commission VI. The study program and questions on Communication Theory proposed by the C.C.I.R. were taken under consideration by Sub-Commission VI-1. A working group has prepared a report

on those aspects of the subject which can be treated on the basis of existing knowledge. Other aspects of the field are on the agenda of the Sub-Commission for its consideration during the following three year period.

There is one topic that the C.C.I.R. has submitted to Commission VI on which the Commission is at present not in position to make a major contribution. It deals with the effect of quasi-impulsive and atmospheric noise on receiver sensitivity. The C.C.I.R. topic is closely related to one referred to Commission VI three years ago by Commission IV.

Dr. STUMPERS of our Commission is willing to undertake the responsibility for a working group to deal with the subject. Our problem is to recruit members of the working group and to this end, we offer resolution 2.

One of the encouraging features of the program of Commission VI at this General Assembly is that we seem to have achieved something of a sense of unity between the three Sub-Commission areas in contrast with the sense of diversity that marked previous meetings. At its administrative session the Commission decided that we should continue the Sub-Commission structure for another three year period with the following Chairmen :

VI-1 ..... Prof. VAN DER POL
VI-2 ..... Prof. TELLEGEN
VI-3 ..... Prof. SINCLAIR

The recommendation of the Commission was submitted to the Executive Committee.

The Commission feels that much has to be gained from joint sessions with other Commissions in overlapping fields and topics that more such sessions will be featured at the next General Assembly.

As to other future plans we refer to the recommendation for further research we should mention particularly the proposal for a second international Symposium on Electromagnetic Theory to be sponsored by Commission VI and to be held in Toronto, Canada in 1959. The organization and support will be patterned on the Michigan Symposium of 1955.

The Commission in its sessions on circuit theory felt most keenly its loss by the death of Prof. Marcel BAYARD of the French National

Committee Prof. BAYARD who was noted for his outstanding contributions in the field of circuit theory played an important role in the development of our Commission.

For the success of its program the Commission is indebted to the efforts of its many members and the cooperation of the National Committees in gathering outstanding contributions. On behalf of the Commission I wish to express our deep appreciation for the assistance of Col. HERBAYS and the staff of the Secretariat in getting our work under way.

Resolutions and Recommendations

1. The Commission notes with regret the passing of Prof. Marcel BAYARD, an outstanding representative of the French National Committee in the field of Circuit Theory.

Resolved that a memorial be published in the Proceedings of the XIIth General Assembly.

2. Resolved that National Committees be urged to add to their membership circuit and communication engineers interested in operational problems of communication circuits to supplement the current theoretical work in the circuit field.

3. Resolved that National Committees be urged to add to their membership engineers and scientists interested in propagation in anisotropic media to contribute to the work of Commission VI in such areas as gyrators, isolators, etc.

4. Recommendation on organization of program for Commission VI for the XIIIth General Assembly : The main body of the program shall consist of discussion sessions on chosen topics introduced by invited papers, and that there shall be one or more sessions on contributed papers. Contributed papers shall be presented only if the author is present.

5. That a working group be named to study and report on the classification of surface waves.

6. That Commission sponsor an international Symposium on Electromagnetic Theory in 1959 ; Toronto, Canada is being considered as the location.

7. That work on the monograph on communication systems be continued during the following three year period.

RECOMMENDATIONS FOR FUTURE WORK

1. The field strength in the neighborhood of antennas and obstacles under time-harmonic and transient conditions.

2. Wave propagation in anisotropic media.

3. The theory of surface wave and leaky wave antennas.

4. Calculation of the diffraction fields for dimensions of bodies in the resonance region.

5. Study of synthesis problem for actual antennas and scattering systems.

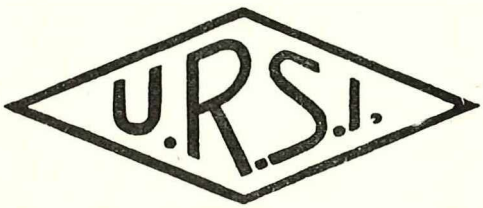
6 Scattering from periodic and « disturbed » periodic structures.

7. Study of broad-band antennas.

8. Study of design problems in large aperture antennas ; comparison between reflector antennas and arrays.

9. Application of communication theory principles to antenna design and scanning problems.

INTERNATIONAL SCIENTIFIC RADIO UNION



Proceedings of the XIIth General Assembly

held in Boulder, Colorado, U. S. A.
from August 22nd to September 5th, 1957

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On Radioelectronics

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COMMISSION VII

On Radioelectronics

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Yugoslavia : Prof. R. MARKOVITCH, c/o Prof. Ing. A. DAMIANOVITCH, Faculté d'Electrotechnique, 6, Stevana Sremca, Beograd 2.

List of Reports and Papers Submitted to the Commission

The asterisk indicates reports published in this part.

O = Original text in English

F = Original text in French

N°	Titles and Authors
103	Electron waves in periodic structure, L. A. WAINSTEIN (E).
138*	Report of the British National Committee to Commission VII, C. W. OATLEY (E).
144*	Report of the Swiss National Committee to Commission VII, Prof. SCHAETTI (E) (F).
146	Oscillation phenomena in gas discharges, W. P. ALLIS, Massachusetts Institute of Technology, Cambridge, Mass. (E).
147	The physics of the cathodes, L. S. NEEGARD, R. C. A. Laboratories, Princeton, New-Jersey (E).
148	The physics of semiconductor devices for radio application, W. SHOCKLEY, Shockley Semi-conductor Laboratory, Beckman Instrument Ltd, Mountain View, Calif. (E).
149	The source and nature of noise in electron beams, J. R. PIERCE, Bell Telephone Laboratories Incorporated, Murray Hill, New-Jersey (E).
164*	Report of the Italian National Committee to Commission VII (E).
180	On the space charge wave-length of perpendicurarly inhomogeneous electron stream, O. E. H. RYDBECK, Research Laboratory of Electronics, Chalmers University of Technology, Göteborg, Sweden (E).
181	An experimental investigation of space charge waves in a finite velocity gap, O. STEINSTÖ, *Ibid.* (E).
182	Space charge waves in an electron beam with variable velocity, S. OLVING, *Ibid.* (E).

N°	Titles and Authors
183	Representation of the complexe propagation constants of a travelling wave tube on a Smith diagram, same author (E).
189*	Report of the Canadian National Committee to Commission VII (E).
196*	Report of the German National Committee to Commission VII (E).
203*	Report of the Japanese National Committee to Commission VII, M. KOTANI, T. OKABE, T. MUTO, G. M. HATOYAMA, Y. KOIKE, Y. ASAMI (E).
208*	Report of the Polish National Committee to Commission VII (E).
219*	Report of the Swedish National Committee to Commission VII, H. WALLMAN (E).
227*	Report of the Netherlands National Committee to Commission VII (E).
238*	Report of the French National Committee to Commission VII (F).
304*	Report of U. S. A. Commission VII (E).

Reports of National Committees

Canada

N° 189 — Report of National Commission VII

The Physics of the Cathode

Theoretical and experimental studies of the methods of measuring the emitting properties of thermionic emitters have been made (1, 2) at the National Research Council. The mechanism of detection of microwave frequencies in thermionic diodes has been investigated and a theory developed to explain the detection effect (3). Methods and apparatus have been developed for the measurement of extremely low pressures (4, 5). A low-frequency periodic fluctuation in thermionic tubes with oxide cathode has been investigated (6).

The Physics of Semi-Conducting Devices for Radio Application

A number of instruments have been built at the Canadian Marconi Company laboratory in preparation for work on the semiconductor silicon and rectifying junctions made using silicon. These include crystal puller, Hall effect and conductivity measuring instruments etc. While no fundamental work proper has been done as yet, present effort is directed towards studying the properties of *p-n* junctions. Several of the semiconducting intermetallic compounds were synthesized and purified by zone refining.

An apparatus has been constructed at the National Research Council for the preparation of monocrystalline silicon of controlled impurity. The properties of silicon are under investigation.

Experimental and theoretical studies at the University of British Columbia of the statistical properties of avalanches in silicon under high fields show that the process consists of a randomly bistable system in which the transition probabilities between the

states of low and high conduction are determined by the excess of the applied voltage over a threshold voltage. A circuit element of this type exhibits the unusual feature that its macroscopic current-voltage characteristic is dependent upon the source resistance used to supply the measuring voltage. The intrinsic parameters of the avalanche process are interpreted in terms of the stochastic nature of the initiation and cessation of the discharge. This study provides an evaluation of the magnitude and spectrum of the fundamental fluctuations in voltage and current in avalanche diodes.

Theoretical investigations have been made of the fluctuations in a semi-conductor when in thermal equilibrium and when illuminated in black body radiation at a temperature different from that of the crystal. The ratio of thermalization time to lifetime of carriers having excess energy determines the fluctuation e.m.f. in the latter case. In degenerate semi-conductors the fluctuations of carrier density are depressed by a factor exactly corresponding to the departure of the diffusivity/mobility ration from kT/e. The effects of a random spatial distribution of impurities in a semi-conductor modifies its conductive and photoconductive properties and also leads to a photovoltaic e.m.f. on illumination. The principle of detailed balance has been used to relate the fluctuating photo- and thermoelectric e.m.f.'s in inhomogeneous semi-conductors with corresponding components of resistance.

Following the work done at the University of Toronto on iodine as a molecular solid, work is in progress on external photo-electric effect of ionic crystals and some preliminary results have been obtained.

The Source and Nature of Noise in Electron Beams

Noise in electron streams has been examined in several independent experiments at MacGill University. The noise at the anode of an electron gun has been measured in a sealed-off tube by means of gaps attached to a cavity resonator through which the beam passed. In these experiments, the pressure was of the order of 10^{-9} mm Hg. Noise current modulation at the anode was investigated over the frequencies 200 to 300 Mc/s for anode voltages ranging from 100 to 1000 volts. In another experiment a continuously pumped system was used to investigate the noise

current fluctuations in an electron beam as a function of distance between an electron gun and the measuring cavities, as a function of frequency, and as a function of voltage. The experiment yields information on both the noise current modulation and the noise velocity modulation at the anode of a space-charge-limited electron gun. The experiments have been concluded, but the data have not yet been completely analyzed.

Gas Discharge Phenomena

Following earlier work at the University of Toronto in which it was shown that the $^3P_0$ neon metastable state has a complex decay process, it was decided to measure in the same gas with the same discharge the lifetime of free electrons by microwave methods. It has been shown that the ion decay is not related to either lifetime of the $^3P_0$ state. Feeding of the metastable $^3P_2$ state by recombination is just appreciable at the highest pressures used.

Modern electronic, excitation, gating, and recording techniques have been used to follow the decay of the nitrogen afterglow over an intensity range of nearly $10^6 : 1$. The accuracy is very much greater than in previous work. Three processes are evident; an initial bimolecular process, a second bimolecular process, and a purely monomolecular process which determines the final decay in all cases.

It is shown that the first bimolecular process of the afterglow draws both active bodies from a common population. An activation energy of 900 cm^{-1} is necessary for this afterglow process. The second bimolecular process involves two bodies possessing monomolecular decays independent of afterglow process and drawn from different populations. Negligible activation energy is required for the afterglow from these. This process is quenched by oxygen and requires a minute impurity believed to be hydrogen. The final monomolecular decay displays the well-known diffusion-collision decay constant at higher temperatures. The effects of diffusion are greatly reduced by a monomolecular layer of oxygen on the walls. An aggregate is involved with a dissociation energy of 5600 cm^{-1}. Reasons are given for believing that the first bimolecular process is recombination of nitrogen atoms with oxygen molecular catalyst of the order of a few parts per

million and that the second process is collision of two different vibrationally excited ground states of the neutral nitrogen molecule giving an afterglow with a hydrogen molecular catalyst also of the order of a few parts per million.

Interaction of Waves in Electron Streams with Propagation Srtuctures

Measurements on modulated beams of electrons at McGill University have been made which were intended to check the applicability of the electronic equation for several distributions of steady potential along the beam. These measurements were made for a range of beam currents and voltages. A continuously pumped system was used in which was located a buncher cavity, a catcher cavity and an intervening interaction space on which the required potential distribution could be imposed. The distance between the buncher cavity and the catcher cavity could be adjusted by external manipulation without breaking the vacuum seals. Other similar measurements were made on sealed-off tubes in which the pressure was of the order of 10^{-9} mm Hg. On the whole, the electronic equation can be used to predict the power transmitted through such a system. Discrepancies in the maximum power transmitted, which were independent of pressure, were discovered when the time independent current in the beam was varied so that, in succession, the first, second, third, and so on, space charge wave maxima of current modulation occurred at the catcher cavity.

A number of the properties of a periodically obstructed cylindrical waveguide have been measured for the purpose of developing techniques of measurement and of comparing predictions from several forms of theory with the measured values. It has been concluded that the approximate forms of electromagnetic field theory, which are sometimes developed for such structures, are of limited use. Lumped circuit analogues are valuable in forming a general picture of the properties of the structure, but quantitative predictions made from them are unsatisfactory. The techniques for measuring some of the properties of the guide are excellent but the precision of the results from perturbation experiments (which are intended to yield data on the form of the fields and on the circuit impedance) is apt to be low.

The anomalous retarding-field effect in electron streams and the associated oscillations on the stream are being investigated at the National Research Council.

Formation, Focussing and Propagation of Electron Beams

A study of the production of electron beams using Pierce-type electron guns has been carried out at McGill University and the behaviour of beams in no magnetic field, a constant field and a periodic field has been studied. The agreement between theory and experiment was satisfactory, although in general the theory over-estimated the effectiveness of a magnetic focussing field. Phenomena due possibly to the existence of positive ions in the beam were observed. The further development of techniques used in dynamic vacuum systems was shown to be desirable.

Theoretical and experimental work on electron beams focussed by periodic magnetic fields has been done. Principle consideration was given to beams generated outside the magnetic field which enter the field under controlled conditions. The existing theory has been reviewed and extended. The equation describing the trajectory of an edge electron was solved on an analog computer. The results of these solutions have been analyzed. Special attention was given to the conditions under which the solution will be valid. Point by point steady-state measurements were taken. These measurements showed that good focussing can be achieved. The band nature of the beam propagation was illustrated. Pulsed measurements were performed which indicated that positive ion generation determines the time taken to initiate a beam.

An experimental study of the elastic reflection of slow electrons (0-40 eV) from metal surfaces is being made at the National Research Council. The results obtained from polycrystalline targets of Ta and Cu have been published (9). Monocrystalline targets are presently being studied.

Ferromagnetic Materials, Ferrite

Procedures for growing flake-shaped single crystals of barium titanate from a solution in potassium fluoride by the Remeikas method have been studied at Canadian Marconi. Crystal cutting,

and coating processes for making these crystals into memory capacitors have also been investigated and reported on. Domain motion in barium titanate under the influence of electric fields gives rise to changes in the state of polarization of transmitted polarized light. Light modulation can be obtained from low applied voltages. This effect has been studied and related to the ferroelectric crystal phenomenon used for information storage. Light transmission and the effect on it of an applied electric field was described for ferroelectric barium titanate crystals. Distortion measurement of light modulation in the audio range was reported.

The Physical and Chemical Structure of Dielectrics

A laboratory for dielectric work over a very wide range of frequencies has recently been established in Ottawa. D. c. conductivity measurements of dielectric samples have yielded useful results. Measurement of dielectric constant and loss of ceramic samples of somes stannates and cerates with perovskite-type crystal structure as a function of frequency and temperature in the range 100 cps to 1 Mc and −196° C to about 400° C has yielded useful results about the dielectric dispersion, but no phase transitions were found.

The Study of Components

The Defence Research Board is investigating the conducting properties of sintered oxide mixtures with a view to the possible use as high temperature components. Specifically the search is for compensating physical mechanisms that will produce constant conductivity with temperature variation. Zinc oxide — titanium dioxide systems with such a mechanism have been prepared, electrical properties measured and the influence of various heat treatments explored. Conductivity and Hall coefficient measurements have been made and activation energies derived. Work is continuing on studies of gain structure and its effects on conductivity.

Work is being carried out on the investigation of anodic oxide films at the Defence Research Board, Ottawa, and also at the British Columbia Research Council, Vancouver. This project

is directed towards the improvement of electrolytic capacitors or other capacitors utilizing thin oxide films. A fundamental investigation of the properties of anodic oxide films on aluminium and tantalum is underway. This includes such topics as the effect of surface treatment before anodization, theory of oxide formation, leakage currents below the formation voltage, a. c. impedance, rectification and electroluminescence in the films.

Canadian Marconi is working on two contracts with the Defence Research Board to study the reliability of fixed and variable carbon composition resistors. About 1200 fixed resistors have been placed on life test under various conditions of load, temperature, and humidity, and the resistance measured at regular intervals by means of ALTREC. The study on variable resistors has been concentrated on noise, both rotational and stationary. Equipment has been built which treats the resistors as a four-terminal device, automatically measuring the noise between various terminals under various conditions of loading and at regular intervals during rotational life. The noise is presented on two oscilloscope tubes and on peak reading and integral reading meters which are photographically recorded. Twenty variable resistors may be handled by this equipment.

Solid State

The photoconductivity of thin films of CdS and CdSe has been investigated at Canadian Marconi. The influence of type of activator, heat treatment, electrode materials and other factors on trap density and mobility of electrons in the conduction band has been studied. Current carrier inertia effects in photoconductors have been studied and described They are determined by the lifetime of the free carriers and by the ratio of trap densities to the ratio of free carriers. The measurement technique and values for these quantities have been prepared for evaporated CdS and CdSe photoconductive cells.

The temperature dependence of the work functions of thick evaporated polycrystalline copper and silver films was measured at McGill between 50° C and 500° C using the Zisman method to measure the contact potential of a heated surface relative to a reference surface at a constant temperature. Reproducible results were obtained — minus 57 and minus 134 microvolts per

degree for copper and silver respectively. The possibility of error due to heating of the reference surface is now under investigation. A theoretical study of the temperature dependence has achieved a qualitative explanation of the experimental results.

The temperature dependence of the work functions of thick polycrystalline evaporated films of potassium and sodium has been investigated using as a test surface the anode of a diode operated at constant current under retarding field conditions. From -190° C to 20° C the temperature dependence of both clean and contaminated films of potassium was found to be minus 180 ± 20 microvolts per degree. Preliminary results in the case of sodium indicate results of the order of minus 500 microvolts per degree. A theoretical investigation allowing for the anisotropy of these metals is in progress.

The temperature dependence of the work function of single crystal faces of copper is being studied. In this research the use of the retarding field diode technique is proposed in which the work function changes of an indirectly heated single crystal anode will be investigated.

Fundamental studies of the properties of electrons in insulating solids have been made at the National Research Council. These have been chiefly concerned with the thermal and optical properties of trapped electrons in ionic crystals (11, 12). Theoretical work, chiefly on colour centres, is continuing and accompanying experimental investigations are now in progress.

Optical and electrical properties of molecular crystals are also being investigated experimentally (13, 14). Alkali halide, silver halide and molecular single crystals for the above work have been grown in the laboratory.

A vacuum tube using the velocity-jump principle has been built at McGill to amplify microwave frequencies in the vicinity of 10 000 Mc/s (X-band). The design of the tube was based on a similar structure that has been built to operate at a lower frequency. A series of experimental measurements were performed to determine the operating characteristics of the tube.

A general theory previously developed for space-charge wave amplifiers was applied to the operation of the tube, in conjunction with approximations made to the theory of coupling to electron beams by means of helices. The measured gain obtained in this

research agreed reasonably well with that predicted by this theoretical development. Conclusions are drawn regarding the operation of coupling helices, and the effect of small gaps in the amplifying section of the tube.

The « omegatron », a radio-frequency mass-spectrometer, has been studied at the National Research Council, and numerous improvements made in the design of this instrument.

Secondary Emission

A new method has been devised at the University of Toronto to distinguish experimentally between simultaneous emission of 1, 2, 3, etc. electrons in a single secondary emission event. Results have been obtained for the relative probability of emission of 1, 2, 3, 4, 5, 6, 7 electrons from Be Cu at primary voltages of 50-450 volts. Changes of these relative probabilities have also been followed. Absolute probabilities of these and for zero emission as well are being determined.

Radiation Detection

The limiting sensitivity of various forms of radiation detector has been analyzed, at the University of British Columbia, from the view point of information theory. Consideration of the number of degrees of freedom of radiation with a given power distribution in solid angle, frequency and polarization yields the entropy of the source of information. The statistical nature of the photon-electron interaction in the detector is evaluated as equivocation. The resolving power of the detector in terms of spectral response signal/noise ratio, bandwidth and relaxation time can be related to Shannon's analysis of communication. The upper bounds imposed on the rate at which information can be handled are capable of physical interpretation in terms of the transformation of the ensemble of radiation parameters into that of the observable quantities indicated by the detector.

Engineering Electronics

A study of the behaviour of statistical quantities of components or devices in various environments has been facilitated at Canadian

Marconi by the invention of ALTREC, an instrument for automatic life testing and recording of electronic components. Components or devices are kept in, or cycled through, certain environments, and their parameters are measured at predetermined intervals. The readings are printed together with indexing data on paper tape. A patch cord programming system allows flexible control of the test conditions on up to 10 groups of 100 components each with possibility for expansion when needed.

D. c. degeneration by means of a bypassed resistor is being studied as a means of holding tube transconductance constant as the tube ages. Unlike negative feedback this type of stabilization has not the disadvantage of decreasing the gain of the circuit. The improvement in stability over an ordinary cathode self-bias amplifier (bypasses resistor taken to ground) is a factor of 3, but varies for various tubes.

An investigation was started some years ago into the possibility of forecasting cathode lifetime of an electron tube by means of a test run of the order of 100 hours. Experiment with batches totalling several hundred tubes and previous work in the field indicated the factors to be observed during this period, and life tests have shown some correlation between the change in saturated emission and tube life. Analysis of the results after nearly twenty thousand hours of life tests was presented. The work is not concerned with the effects of environmental or mechanical design aspects of life termination. Due to ambiguities in methods of measuring cathode interface resistance, its contribution to life was not exhaustively studied, but its effects can be shown from life tests on batches with active and passive cathode sleeves.

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France

N° 238. — Report of the National Committee to Commission VII

(*Translation*)

According to the recommendations of Comm. VII (Chairman, Dr. Woonton), four items were retained for discussion at the XIIth General Assembly :

A. The Physics of the Cathode ;

B. The Physics of the Semi-conductors, in view of their applications to Radio electricity ;

C. The Source and the Nature of Noise in Electron beams ;

D. Oscillation Phenomena in Gas-Discharges.

These items have been studied by four working groups, respectively under the chairmanship of :

Prof. GRIVET (Physics of the Cathode) ;

Prof. GOUDET (Semi-conductors) ;

Dr. WARNECKE (Noise in electron beams) ;

Prof. LAPORTE (Gas-discharges) ;

which accepted to collect and summarize with their collaborators, the principal studies made in France on these subjects.

1. — THE PHYSICS OF THE CATHODE

French work on oxide-cathodes have always been numerous but, in general have given rise to few publications, because they are principally made in industrial laboratories where it is common practice to consider the results as secret. The authoritative meeting in Paris (week of June 24, 1954) stimulated greatly at this epoch the publication of the most important results, in N^{os} 51, 52, 53 and 54 of the review *Le Vide* (particularly in the special issue N^{o} 51, May 1954, 392 pp.).

The following years have been less fruitfull as long as publications are concerned : only the group of Lyon, directed by Mr. Mesnard, described in numerous articles of the review *Le Vide* its experimental investigations : measurements on earth-alkaline carbonate fritted cathodes with addition of several metals, particularly zirconium and tungstene, measurements on thorine and zircone-thorine cathodes. The most interesting results concerned the emission decay in pulsed operation.

Besides other contributions describing methods for preparing or activating the cathodes, measurements on an empirical set of various cathodes, an article published in the « Cahiers de Physique » proposed an explanation of the emission decay in thorine, based on the assumption of a conduction similar to those occurring in the *n*-type semi-conducting material. With an assumption on the donors'concentration, which should draw together the emission mechanisms in thorine and in the earth-alkaline oxides, a semi-empirical formula representing at best the observations has been obtained.

II. — The Physics of the Semi-conductors, with their Applications to Radio Electricity

Since the XIth General Assembly in the Hague, research in France on semi-conductors Physics, has been made on a wider program. Work has continued, new goals appeared fruitful, new laboratories were opened to an increasing number of investigators.

Each Faculty-laboratory was concerned with a defined question, either experimental or related with the internal structure of the semi-conducting material.

The Laboratory of Theoretical Physics of the University of Algiers, under the direction of Mrs. Blanc Lapierre and Nifontoff, continued its work on the simultaneous variations in the resistance and in the scintillation effects of crystal rectifiers and thin metal layers, as a function of the Dc-current intensity. The scintillation effect vs. illumination and external polarization was especially investigated for photovoltaïc cells. Work in progress will lead, in the near future, to a more precise definition of the thin granular metallic layers-properties (influence of the nature of the metal and of various parameters of the layer's formation, on the scintillation effect and on the resistance), as well as to a theoretical explanation of the properties of these layers, especially, the degree of validity of Nifontoff's Theory which assumes that these granular layers are constituted by metallic islets embedded in a semi-conducting substratum.

The Physical Laboratory (Mr. Perrot) has continued its research on the properties of thin layers and cooperated in a part of the previous investigations ; work on powdered semi-conductors has also been made.

The Faculty of Rennes (Mr. Freymann) continued its work on the solid state Physics, using the radioelectrical dipolar absorption method This method leads not only to results on the dielectric properties for numerous substances, but also allows to investigate the influence of light on semi conducting materials, the influence of doping, and, as a consequence, the purity of the material as well as the crystalline lattice defects. This method may then be useful in the determination of the energy levels of semi-conductors.

The Institute for General Physics of Lyon (Mr. Mesnard) studied

the current-voltage characteristics of the germanium-metal rectifiers, and the deterioration processes of these characteristics.

The Faculty of Sciences of Paris, in its numerous specialized laboratories (physical chemistry, physical research, etc.), investigated very particular aspects of these items (relations between phosphorescence and semi-conductor physics, accurate determination of energy levels, etc.)

The Physical Laboratory of « Ecole Normale Supérieure » (Mr. Aigrin) studied surface properties of semi-conductors. This study has been effected along two principal ways :

(1) Systematic reconsideration of previous investigations on germanium and silicium.

(2) Study of surface properties of ZnO and TiO_2 in relation with gas chemisorption, in view of precising absorption kinetics. Numerous results have already been obtained.

The Atomic Energy Board, studied the direct conversion of radiation into electric energy, by irradiation of semi-conducting junctions, and the application of these junctions as nuclear radiation detectors.

The Laboratory of Magnetism of the « Centre National de la Recherche Scientifique » (Bellevue, Mr. Guillaud) investigated, in parallel with germanium and silicium, the indium and aluminium antimoniates and their applications ; furthermore, the study of thermopiles is near completion.

The Bellevue Laboratory largely cooperated with other research laboratories, especially with the « Centre National d'Etudes des Télécommunications » which for example, is studying the possibility of formation of pure or doped germanium deposites in thin layers ; the matter of investigating these layers is referred to M. Trillat's group.

Miscellaneous

A large cooperation with the Faculty laboratories allows the Bellevue laboratory to investigate the subject in various directions. With the *Physical Institute of Strasbourg*, this laboratory has studied the questions of semi-conductor spectra, of relations between semi-conductivity and magnetic behaviour, etc.

The Faculties of Sciences of Grenoble, Marseille, Nancy investigated the subject under various specialized points of view, studying the possibility of obtaining germanium and its alloys by electrolyze, the luminescence of thin semi-conducting films, etc. *The Paris Observatory* (Mr. Lallemand) investigated the working mechanism of cadmium-sulfide photoelectric layers.

In private laboratories, studies were made in parallel with production and allowed to improve knowledge on crystal structure and semi-conductor's physics. The French Company Thomson-Houston, the « Compagnie Générale de TSF », the « Laboratoire Central des Telecommunications », amongst others, are contributing largely to general progress.

With this progress, new opportunities are discovered and new application fields are opened for technics and research. The semi-conductor's physics has magnificient perspectives ; it remains also a privilegiate way of approach for the solid state physics.

III. — Sources and Nature of Noise in Electron beams

A. — *Type « O » Tubes*

Noise of ionic origin has been observed, at the « Compagnie Générale de TSF », in various TPO — tubes (wave propagation tubes), in Carcinotrons « O », and in reflex klystrons, and gave rise to some studies.

The following observations were made in particular on a TPO amplifier where an electron beam of 20 to 30 mA was accelerated by a voltage of 900 to 1000 V :

1. The studied phenomenon consisted in a modulation of the amplified signals, in amplitude or in phase, at frequencies from some hundreds of Kc/s to some Mc/s. These modulations appeared as a continuous noise on bandwiths of some Kc/s, but occurred also at well defined frequencies. Low frequency modulations (of the order of some Kc/s) may also appear in superposition with the preceding ones.

Simultaneous modulations at the same frequencies are observed in the circuit current ; the modulation depth is in connection with the slope of the current-voltage characteristics. Its oscillographic shape is often that of pure sinusoïd.

2. The intensity of these parasitic lines or bands depends on pressure and beam geometry.

Improving the vacuum has no important effect above a certain treshold ; below this level the noise disappears completely. The treshold varies considerably with the beam geometry and may correspond to 10^{-6} mm Hg or to some 10^{-9} mm Hg for focalisations differring as little as to keep the same current in the circuit.

The role of the beamshape also is considerable when, at fixed pressure, the voltage is varied. In this circumstance, the noise exhibits periodic variations when the voltage (order of magnitude 50 to 60 V in the present experience) increases ; this periodicity seems to be related with the number of undulations over a beam length. The noise variations over a period may be 30 db or more, the minima being frequently as low as thermal noise.

The magnetic field shape in the gun region plays on the noise level an important role ; voltage intervals without noise, even at considerable pressure (e.g.10^{-6} mm Hg). These intervals widen when vacuum is improved ; a convenient value is e.g. 20 to 30 % from 10^{-7} to 5.10^{-8} mm Hg.

3. That these parasitic oscillations are of ionic origin is proved by their disappearance when pressure is reduced below a certain level. On the other hand the order of magnitude of the observed frequencies is well explained by oscillations of nitrogen atoms in the voltage depressions in the beam. No quantitative agreement however has been obtained, and the sign of the frequency variations not always corresponds to simple predictions (for example, an increase in frequency was observed in case of cathode under heating, an operation leading to an improvement in vacuum).

It seems that in every case, we must attach considerable importance to the voltage depressions, which may cause the ion capture.

B. — *Type « M » tubes*

1. *Introduction.* — In « M » tubes the noise is of several orders of magnitude greater than for the corresponding « O » tubes. Two methods may be used for studying the origin of this anormal noise.

The first consists of infecting a flot beam in a space limited by two parallel plates, in which crossed magnetic and electric fields are induced. The transit time is finite and the current-density

may be chosen independently of the interaction-space parameters. The fundamental difficulty in this method is to determinate exactly the static initial conditions of the beam and the density and velocity modulation conditions at the input of the interaction space. This method has been used by the group of the « Compagnie Générale de TSF ». The origin of the noise in the beam (diocotron effect) and the signal to noise ratio in TPOM tubes and Corcinotron —M have been studied.

The second method consists of studying the blocked cylindrical magnetron. The fundamental difficulty in this method is the complexity of the statical magnetron, which could only be investigated with the aid of calculating machines. This method has been used in France especially by the « Ecole Normale Supérieure » group.

2. *Diocotron effect.* — The instability of an electron beam moving perpendicularly to crossed electric and magnetic fields has been verified experimentally by Guénard and Hubert; these investigators found good agreement between theory and experience. In their theoretical interpretation, the electron velocity variation in the cross section of a rectilinear beam, variation due to space charge, has been taken into account.

After Brillouin, a rectilinear beam is possible only if the plasma frequency equals the cyclotron frequency; this condition is practically never fulfilled. In this case, the velocity-variation in the cross section and consequently the gain are smaller.

Recently, B. Epzstein and independently J.R. Pierce studied a rectilinear beam, infinitely thin and without velocity variation in the cross-section. A deformation of such a beam is unstable.

The time phenomenon in « M » tubes is equivalent to a space instability for flat or hollow beams (type « O »), such as Webster found experimentally.

In the Epzstein model, the gain expressed in Neper/cm is the same as in the variable velocity beam model.

The diocotron -effect theory leads to an explanation of the noise increase in « M »-tubes, but a comparison between theory and the noise measured e.g. by Alfvén et al. is not actually possible, because experimental data are too scarce. From the theory, the noise at constant frequency increases exponentially with

$IB^2 L/V^3$, where I is the current, B the magnetic induction, V the voltage sole-anode, L the length of the interaction space.

From Alfvén's measurements, evidence is found of the relations $IB^2 = ct$ and $IV^{-5/2} = ct$ for constant noise. Additional experiences are then necessary for allowing a sufficiently accurate verification of the theory.

3. *Blocked magnetron.* — Delcroix, studying the blocked magnetron, found instabilities in the current-voltage characteristics due to a change from the monodromic state to a simple bidromic state, or from a bidromic state of order n to a bidromic state of order $n + 1$. This instability appears related with hysteresis phenomena and is accompanied with strong noise.

On the other hand, Delcroix and Coste studied the free oscillations of an operated magnetron, and found a discrete series of resonance frequencies, proportionnal to the cyclotron-frequency. These oscillations are depending on the anode radius, the cathode radius and the space charge. The authors give no analytical relations for comparing the experimental results of Stainsby et al. with their theory.

4. *Noise in TPOM -tube in pulsed operation.* — In the absence of an input-signal, the noise power of the TPOM-tube may be as high as 10 to 20 % of the total power if the beam impedance is of the order of 1000 ohms. With an input-signal, the noise is reduced, but the signal to noise ratio increases with the current and the magnetic field, and decreases with the voltage. This phenomenon is qualitatively explained by the diocotron effect. However, a reduction of noise is also experienced if a negative voltage is applied to the sole ; this circumstance is not explained by the conventional theories. A signal to noise ratio of 30 to 40 db has been obtained for an pulse-power of 2 MW at a voltage of 80 KV and a beam impedance of 1700 ohms.

The signal to noise ratio is very sensitive to the pulse shape ; a sharp rise and fall of the pulse and an homogeneous magnetic field reduce the noise.

5. *Carcinotron « M ».* — Convert and Doehler measured the noise to signal ratio in carcinotrons « M ». This ratio is of the order of 10^{-14} to 10^{-16} and of two to three orders of magnitude inferior to that in the reflex klystrons and the carcinotrons « O ». The

noise increases with the current, circumstance which is well explained by the diocotron effect. On the other hand, in « O » -tubes, the noise decreases with the current.

6. *Summary.* — The beam instability in « M » -tubes explains qualitatively the strong noise existing in diocotrons, trochotrons, etc. But a quantitative comparison is not possible because the experimental data are still unsufficient.

IV. — Oscillating Phenomena in Gas Discharges

Besides the fairly numerous works in France on the *general study of plasmas in ionized gases*, we have to mention the following studies :

1° A theoretical work of J. Salmon on the *determination of the onset conditions for H F. gas discharges at low pressures.* These pressures are as low as 5 to 50 μ Hg (the lower limit corresponding to electron mean free paths of the order of the dimensions of usual discharge tubes). Mr. Salmon takes into account, for maintaining the discharge, the secondary electrons emitted from the tube walls by collisions with electrons oscillating in the field. A set of theoretical curves is given for representing, at various excitation frequencies (in the interval 25 to 70 Mc/s), the variation of the onset voltage with pressure. These curves are in good agreement with the experimental curves obtained by Miss Chenot in France and by Gill and Von Engel in England.

2° A thesis from F. Cabannes on the *study of the discharge by induction in noble gases.* This author investigates the pure induced discharges (without electrodes) in a glass or quartz tube of 3 to 4 cm-diameter and of about 10 cm in length ; this tube is placed coaxially in the nudian region of a solenoïd excited by a H. F. current (frequency about 1 Mc/s, power 1 to 2 kW). The author applies to the gas (Ne, Ar, Kr and Xe), under pressures varying between 10^{-3} and 100 mm Hg, the theoretical formulas for the heating of solid samples of various resistivities. These formulas lead him to compute the sample conductivity from measurements of 1) the H. F. current-intensity, 2) the dissipated power in the sample. Calorimetric measurements of the heating of a water-stream in an enclosure around the tube are used for

power-determination. Account taken of the fact that the gas-conductivity varies from one volume-element to another; Mr. Cabannes gives an approximate value of the conductivity.

Various simplifying but acceptable assumptions lead him also to a first determination of the electronic temperature; a second determination, in good agreement with the first, is obtained by the two floating probes'method. The use of the latter confirms the hypothesis that the electron velocity distribution is maxwellian, In spite of radial variations in the induced field intensity, and of concomitant heating differences, the electronic temperature is practically the same on the tube axis and at the vicinity of the walls. These temperatures must probably equalize themselves by thermal agitation and electron diffusion. A spectrographic study of the emitted radiation was also made besides the electrical one.

3° *Oscillating phenomena of mechanical origin.* — Oscillating phenomena, which are indicated by periodic variations in the emitted radiation, occur in gas tubes under short pulse discharges of a condenser through the tube, *even when these discharges are electrically aperiodic.*

Some twenty years ago, a similar phenomenon was observed by Mr. Laporte (1). This investigator formed an image of a segment of the tube on a narrow slit *parallel* to the tube-axis. This image was analysed by means of a rapidly moving spherical mirror which focussed the light beam on a photographic plate; this classical method of the rotating mirror was used in view of a precise determination of the very short durations of the lightnings (one millimeter on the photographic plate corresponding to one microsecond). Moreover, examination of the pictures allowed to distinguish between oscillating discharge lightnings and those corresponding to an aperiodic discharge of the condenser. Very curiously enough, on aperiodic discharges picture, some bright and equally spaced lines were observed, corresponding in fact to periodic maxima of emission; a second interesting feature

(1) M. Laporte and R. Pierrejean, « Structure fine des éclairs lumineux obtenus en déchargeant un condensateur à travers un tube à gaz ». *J. Phys. et Rad*, 7, 1936, 248.

was that the lines appeared tilted in the same direction, independently of the polarization of the electrodes.

A deeper investigation was then delayed. Recently, Mr. Cloupeau was confronted with a similar phenomenon in his studies on the instantaneous spectral distribution of the radiation from lightning tubes and on the modifications in this distribution during the lightning process. The rotating mirror method was also used, with a narrow slit placed *perpendicularly* to the tube axis ; for aperiodic discharges, he obtained photographic records on which evidence was found of periodic variations in the emitted radiation, these periodic variations are the same for all wavelengths.

Experience indicates that the distinctness of the maxima depends on the conditions of onset for the discharge. According to these conditions, the discharge may begin as a narrow luminous channel, or occupy almost the full cross section of the tube. More the discharge appears filiform, more are distinct the observed periodic maxima. Mr. Cloupeau has given the following interpretation of these phenomena : when a very intense current passes through the tube in a narrow channel (some hundreds or thousands Amperes), this current must cause in the very limited volume of the gas a very great and very sudden temperature rise, origin of a shock wave ; this wave is then propagated towards the tube walls with a considerable velocity and eventually experiences multiple reflections.

The obtained records may be explained if one admits that the shock wave front behaves like a moving and highly concentrated luminous source. This explanation is supported by various authors : S. J. Drabkina showed that shock wave propagation formulas apply correctly to the observed phenomena when an initial narrow channel of a condensed discharge expands ; F. Gowler attributed also to shock waves the luminosities observed by Rayleigh in tubes communicating side-ways with the discharge tube.

Shock wave reflection may also occur on every solid wall placed on the propagation path ; in particular, besides reflection on side walls, reflections on the tube extremities are produced.

Such a reflection was probably cause of the tilted lines observed by Mr. Laporte. The tilt may result from wave propagation

along the axis ; the same end serving as reflecting wall (probably the nearest one from the source) caused also the phenomenon to occur independently of the polarization of the electrodes.

Photographic records obtained by Mr. Cloupeau allowed him to determine the shock wave propagation velocity as a function of the discharge conditions and the gas temperature.

These oscillating phenomena of mechanical origin appear interesting for obtaining locally extremely high temperatures. On the other hand, they come into account in complicating the study of the time variations in the spectral distribution of the lightning : the instantaneous emission of light, and especially of the light constituting the continuous background in the case of the heaviest noble gases, may not be considered as depending only of instantaneous values of electrical parameters.

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II. — Semi-conductor Physics

Owing to the specialization of laboratories studying these matters, it seemed more appropriate to group the bibliography references by laboratories. Henceforth the references are grouped as follows :

I. Faculty of Algiers 1-14
II. Faculty of Grenoble 15-17
III. Institut de Physique Générale de Lyon 18-19
IV. Faculty of Marseille 20-23
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VI. Paris : Laboratoire de l'Ecole Normale Supérieure et Faculté des Sciences 25-43
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XIV. Miscellaneous 79-84
XV. Works on Semi-conductors 85,86

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III. — Noise in Electron Beams

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IV. — Oscillating Phenomena in Gas Discharges

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Germany

Nº 196. — Report of the National Committee on the activity in the field of Commission VII (1954-1956)

Contents

A. The Physics of the Cathode.
B. The Physics of Semiconducting Devices for Radio Applications.
C. The Source and Nature of Noise in Electron Beams.
D. Oscillation Phenomena in Gas Discharges.

Remark. — The lists of reference appended to the report will be published in the Proceedings of the General Assembly.

A. — The Physics of the Cathode

I. — *General Review*

A summarizing report on modern thermionic cathodes is given by Morgulis (17). This essay contains numerous references from Eastern Europe.

II. — *Work Function*

An article concerning the theory of work function of metals using an extended Thomas-Fermi-Statistic is published by Oldekop and Sauter (19).

Measurements of the work function of metals and semi-conductors as a function of temperature are reported by Mönch (16) and Böttger (3), using the shifting of grid-plate characteristics. An essential influence of vacuum quality, that is of surface effects of the work function are found.

III. — *Methods of investigation*

(*a*) Dahlke (5) describes a test method for evaluation of cathode emission utilizing the space charge reduction of shot noise. Badly activated parts of the cathode show the full shot noise without space charge reduction.

(*b*) Measurements of gas pressure in electron tubes during life are published by Dahlke and Schütze (6). The method is useful for pressures down to 10^{-9} Torr.

(*c*) An impulse testing method indicating the electrical data of interface layers in oxide cathodes is described by Lieb (15).

(*d*) Weber (24) summarizes optical investigations of interface layers.

(*e*) Using an improved Lenard retarding field method, Boersch (2) finds a velocity distribution of thermical emitted electrons which has a larger spread than the well known Maxwellian distribution.

Veith and cooperators (20, 23) investigate the velocity distribution of electrons in test triodes and space charge loaded electron beams. This method (14) together with other measurements give new informations about the different conditions of activation in oxide cathodes. According to Veith the powerful emission of the hollow cathode (22) is due to deviations of the velocity distribution from Maxwell's.

(*f*) Kallweit and Veith (13) add radioactive C^{14} to the carbonates of the cathode coating. The migration and whereabouts of carbon or its gaseous compounds are observed by autoradiographs during the breakdown of the cathode in pumping as well as in aging. The carbon compounds emitted from carbonates of the coating are absorbed by the parts of the tube, i. e. the plate, and

are very difficult to be isolated again. Consequently isolation failures may occur in form of carbon layers on the micas. Simultaneously cathode poisoning can be found which makes the activation of the cathode more difficult.

IV. — *Core Metals*

Colorimetrical analytic methods for cathode nickel alloys are given by :

Noddack (18) and co-workers for magnesium using the titan-yellow-reaction. Eckert (8) for manganese using the color reaction of formaldoxim and (9) for aluminium as an ammonium salt of aurintricarbon-acid.

Gann (10) for silicon by means of the molybdenum-blue-reaction.

V. — *Cathode quality*

Dahlke (4) reports on measuring methods for the evaluation of cathode quality and especially on the influence of the cathode core upon tube life. He studies further in (7) the influence of the cathode temperature and the current and voltage duty of the tube upon cathode life. This is essentially fixed by the core metal and the gas emitted from the tube.

Having explained the concepts of reliability and lifetime, Schmidt-Brücken (21) gives general informations about his experience with broad band tubes. He reports on his own studies on the influence of cathode poisoning by oxygen emitted from the nickel plate and the influence of additions and impurities upon cathode coating, which is layed on by means of a special electrolytic method.

VI. — *Metal-Capillary-Cathodes*

Benda (1) determines the emission constants of L-cathodes measuring the retarding field current from a counter-electrode. Contrary to the known Richardson plot this method yields A-values of the theoretically expected magnitude.

In (12) Katz summarizes his experiments with L-cathodes performed at Siemens'. In (13) he describes the means to reduce barium evaporation, especially disturbing in this type of cathodes.

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B. — The Physics of Semiconducting Devices for Radio Application

I. — *Semiconductors in general*

(*a*) *Summaries.* — The progress reached in the field of semiconductors during the research period is treated in several summaries. The main interest centers on electronic semiconductors (2) and semiconducting compounds of homeopolar character. In the series of books issued by Schottky (7) « Semiconductor Problems », some current problems of the semiconductor physics are discussed under various aspects.

(*b*) *Theory of Semiconductors.* — With regard to the theoretical treatment of semiconductors, the effective mass of a crystal electron (8), the interaction between electrons and lattice-oscillators (9), as well as the theory of conductivity of isotropic semiconductors (12, 14) are given special consideration.

(*c*) *Magnetic Effects.* — The magnetic effects in semiconductor-crystals are widely discussed after having succeeded in producing semiconductors with extremely high magnetic resistances out of some A^{III}-B^{V}-compounds. The magnetic barrier-layer (18, 19), which can be built up in such semiconductors through depletion at border zones of the charged particles is a new physical phenomenon which offers technical applications as switches.

(*d*) *Optical Effects.* — With regard to the optical effects in semiconductors, the radiation-free recombinations (28, 29) and optical

electron-transitions are treated. A photoelectrical method for the simultaneous determination of life-time and mobility of injected charged particles is given (30).

(*e*) *Miscellaneous.* — The phenomena of electron-fluctuation (37, 38), as well as the recombination of volume in semiconductors at simultaneous surface recombination are examined (41).

II. — *Special Semiconductors*

(*a*) *Germanium and Silicon.* — Concerning investigations of special semiconductor materials, special interest is given to Ge and Si because of their technical application in the construction of transistors and rectifiers. Here the influence of special lattice-disturbances on the electrical properties of Ge (46) is established and the diffusion of Sb, As and In in solid Ge is tested (48). The production of Germanium monocrystals as well as the production of Silicon monocrystals are the subjects of several investigations.

(*b*) *A^{III}-B^{V}-Compounds.* — The knowledge concerning the physical properties of A^{III}-B^{V}-compounds has been widened in the reporting period through numerous papers (51, 53). InP, InSb, InAs, GaP and GaAs were thoroughly studied with regard to their electrical and optical properties (51, 54, 58). Also the Hall effect (59), the differential thermo-voltage (60) and the formation of mixed crystals on various A^{III}-B^{V}-compounds are thoroughly examined (56, 62).

(*c*) *Selenium.* — Because of the great technical importance of selenium rectifiers, even at the present time, problems of their conductivity are investigated in numerous papers (64-69).

(*d*) *Cadmium Sulfide and Cadmium Selenide.* — Several investigations are devoted to the phenomena of conductivity of CdS and CdSe (70, 74). Alternating-light measurements are extended to the built-up and decay of photo-conductivity (71, 73) and to the determination of mobility and distribution of traps (76, 77). It is revealed that the conductivity in these crystals is not due to the microscopic mobility of the charged particles, but is influenced chiefly by the traps (71). The formation of galvanic contact points in CdS-crystals is investigated several times (75, 78).

(*e*) *Copper Oxydule.* — The semiconductive properties of copper oxydule continue to be of interest in view of their importance in the production of rectifiers. Hall-effect measurements are carried out at reduced pressure of oxygen and at low temperatures (84). The behaviour of copper oxydule in the sphere of stability of copper oxide and the electrical conductivity at disturbance of the thermo-dynamic balance are observed (85, 86).

(*f*) *Zinc oxide.* — The electrical conductivity on the surface of zinc oxide-crystals versus adsorbed oxygen and the action of hydrogen is examined (88-90).

III. — *Rectifiers and pn-junctions*

(*a*) *Various Types of Rectifiers.* — Several papers deal with the theoretical bases of the semiconductor metal contact (101) and the *pn*-, *p-i-n*-diode (109, 104, 108) in the field of rectifiers and *pn*-junctions. The relation between the limit voltage and the specific resistance on alloyed Si-diodes is examined. At 300° K, a variation of limit-voltage with specific resistance is obtained, which increases with a 3/4 potency (106).

(*b*) *Miscellaneous.* — Other measurements of photo-diodes serve for the clarification of temperature variation of the photo-current (113) and for the estimation of the influence of diffusion-length and surface recombination on the barrier layer photo-effect in Ge (114).

IV. — *Transistors*

(*a*) *Theory.* — Three theoretical papers describe the behaviour of the drift-transistor. This is a junction-transistor, in the base zone of which a constant electrical acceleration potential is built up for the charged particles, for instance through a suitable inhomogeneous doping. The acceleration potential shortens the delay time of the charged particles, thereby shifting the frequency limit of the drift-transistor to higher values (122).

(*b*) *Characteristic Data and Properties.* — Many contributions deal with the composition, the data of input and output, the characteristics and the quadripole parameters of transistors.

The frequency variation of the characteristic data is investigated

(125, 129, 133, 134). Thereby, the increase of the frequency limit of transistors (132) and the measuring of high frequency parameters represent the most important technical tasks (135).

It is revealed that the equivalent circuit-diagram of the transistor must be complemented for the preparation of its frequency-behaviour through a base-resistance and an admittance, shunted to the collector-connections (129).

(*c*) *Comparison Transistor-Tube.* — A comparative study of a junction-transistor versus an amplifier-tube is made, whereby particularly the linear behaviour and the quadripole equations of the two elements are compared (137).

(*d*) *Special Transistors.* — Furthermore, a switch-transistor with short transition-times is dealt with (140). This special transistor contains in its collecting-electrode an additional metal point, producing a negative region in the electrical voltage-characteristic. This component offers wide possibilities of application as a rapid electronic switch (141).

(*e*) *Circuit Theorie of the Transistor.* — Regarding transistor-circuits, several authors deal with low frequency-amplifiers (146, 148), with the theory of equivalent circuits (145), and with the treatment of the transistor as a lineary quadripole (150, 152). A theoretical study is made on the tensor-analysis of transistor voltage feed-back circuits (151). Also practical considerations are thoroughly discussed, as for instance the stabilization of the direct current working point (154) of junction-transistors, the dimensioning of transitor-wide-band amplifiers (156) and the neutralization in the selective transistor amplifier (155).

(*f*) *Application of the Transistor.* — The practical application of the transistor increases constantly. Transistors are used today for hearing aids (154), in the computer-field (162) and in many other fields of communications. Direct current measuring amplifiers are supplied with transistors (164). Junction-transistors are very suitable for the storage of dual numbers in magnetic memory devices or shifting memory devices in which the storage-elements consist of bi-stable multivibrators (160, 167). High-frequency amplification with transistors becomes increasingly significant (165) since the industry has succeeded in the commercial

production of transistors with frequency-limits of up to 10 Mc/s and more.

V. — *Miscellaneous*

(*a*) *Noise in Semiconductors.* — The noise in semiconductors, diodes and transistors forms the subject of several investigations (168, 175). Schottky's noise formulae are confirmed in junction-diodes within the white-noise spectrum (169). High-frequency noise in transistors is investigated theoretically and experimentally (173, 175).

(*b*) *Variable Resistances and Hall Generators.* — Resistances varying with temperature or voltage represent a new field of application of semiconductor materials (176, 178).

Likewise, the change of resistance in some semiconductors in the magnetic field is leading to new possibilities of application (179), and to magnetic field intensity meters (182, 184).

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V. — MISCELLANEOUS

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(*b*) *Variable Resistances and Hall Generators* :

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C. — Sources and nature of noise in electron beams

In investigating the noise of electron beams the following problems are most interesting,

(*a*) The mathematical display of noise conditions of an electron beam (1), (2), (3), (4), (5), (7), (8), (22).

This shows the suitability of the introduction of noise power waves as well as the complex correlation coefficient.

(*b*) The investigation of the correlation in the potential minimum (5), (10), (13), (24).

The theoretical results of the different authors are contradictory. By use of exact measurement results the investigation of the correlation will be possible and a final diagramm should be obtained.

(*c*) The transformation conditions of electron beams (5), (12), (14), (15), (17), (20), (21).

Generally in all investigations the known transformation formulas of the transmission theory are adapted to electron beams ; only linear transformations are described.

(*d*) The influence of the current leakage to interposed slits or helixes. — No German publication.

(*e*) The influence of the cathode material. — No German publication.

(*f*) The influence of nonlinearities (Large signal, Growing noise). — No German publication.

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15. J. Labus, R. Liebscher. — Plasma wave length and low-noise traveling-wave-tubes. *A.E.U.*, 10, 1956, pp. 421-423.

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D. — Oscillation Phenomena in Gas Discharges

Since the last report was issued in 1954 there has been some activity both theoretical and experimental in connection with

problems of plasma physics as well as with general processes in ionized gases or more special questions. The classification adopted for the publications listed here is chosen in such a manner, that all investigations should be included, which in any form may have contact with problems of wavelike motions and especially of moving space charges in plasmas. Pure electronic plasma oscillations have then to be considered as a very special case, which besides its previous application to travelling wave tubes and similar devices has nowadays found some interest in interpretations of the non-thermal part of the high frequency radio-noise emitted by cosmical objects.

General relations on plasma dynamics have been given by Maecker and Peters (14), who were the first to have included in their investigation the thermodynamics of irreversible processes such as conduction of heat, diffusion, etc. The theory will first find its application in the physics of arc discharges. In a contribution on the magneto-hydrodynamics of compressible media, Larenz (9) succeeded in elaborating a reduction of the number of equations which describe plasma motions. It appears from his relations, that the often supposed and proposed parallelism in the behaviour of mass velocity and magnetic field strength may be better fitted by the former quantity and the electrodynamic vector potential. With restriction to vorticity-free fields of electronic motion Moeglich (15) showed that the hydrodynamical equations for this case may be written in a form very similar to the quantum-theoretical formulation (Schroedringer equation) of the same problem.

More general wave motions were investigated by Richter (17, 18) and Winkler (13). The first author dealt with magneto-hydrodynamic waves, which propagate along a steady homogeneous magnetic field, while the density of the plasma may be variable along this direction. The latter sought for a general dispersion formula with the aim to verify some results of V. A. Bailey (1948). Propagation of waves through inhomogeneous and anisotropic media was studied by Suchy (3), who proposes the use of a special system of coordinates giving some advantages in this general case. Schumann (5, 6) continued his investigations on very long waves, which may propagate between the earth's surface and the ionospheric plasma making allowance for the waves partly to penetrate

the latter medium which acts under the influence of the geomagnetic field.

Schumann (16) also dealt with propagation of waves in a plasma confined between two conducting planes and affected by a steady magnetic field, this investigation being undertaken in view to verify whether there are possibilities to obtain increasing waves. This latter problem together with the search for coupling effects of longitudinal and transversal wave motions will be of interest for the interpretation of radioastronomical phenomena. In this respect an investigation of Luest (8) is to be mentioned. The principal question, whether any separation of charges may occur in a plasma and if so, which would be the upper limit of it, was answered by Larenz (10) finding out that pressure effects will put a limit. Basing on these results, in view to account for non-thermal cosmic noise, the same author (11) proposed a mechanism for plasma oscillations enabled to radiate without a steady magnetic field being necessary.

Some qualitative remarks about the role, which plasma oscillations may play in the interchange of energy in gas discharges, can be found included in a work of Gerthsen and Schulz (7). The influence of the inhomogeneous electron density distribution on the numerical value of the plasma resonance frequency in a discharge channel was studied by Esprester and Haug (4).

A group of investigations may be collected under the title : Behaviour and reaction of plasmas in high-frequency fields. In this section Neuert and cooperators (1) continued experimental and theoretical work about the effects found by Koch and himself such as enhanced luminosity of a high-frequency discharge plasma in the presence of a steady magnetic field. Frequency drift effects of a self-generated oscillator driving a discharge were investigated and suggested for frequency modulation purposes by Haeusler (20), while Seitner (19) studied the change of inductivity of a solenoid surrounded by a plasma. Parameters, which are characterizing a high-frequency discharge between plane electrodes, were discussed and compared with the direct current discharge case by Schneider (2). In a short communication Pupke and Thom (12) dealt with a phenomenon called « rotating plasmoids » in a high-frequency ring-discharge.

Finally some works of Labus (22, 24), Liebscher (24), Mueller

(23, 25) and Poeschl (21, 22), may be listed here. These investigations are intended to be used for applications in the range of travelling wave tubes or similar apparatus and are mentioned here in view of their intense contact with space charge problems and plasma oscillations. A surveying report entitled « Space Charge Waves » containing numerous literature references was worked out by Kleen, Labus and Poeschl (26).

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Italy

N° 164. — Report of the National Committee to Commission VII

Physics of semiconductors

In the laboratory for semiconductors of the « Istituto Superiore delle Poste e Telegrafi (fondazione Ugo Bordoni), the behaviour of the resistivity and Hall coefficient of some germanium monocrystal has been experimentally determined as a function of the magnetic field intensity (nearly up to 1,3 Wb/m^2) for different orientations of the magnetic field and the current by respect to the crystallographic axes of the specimens.

The experimental results have been discussed by considering the germanium energy bands. So far as the *n*-germanium is concerned, the comparison between theoretical and experimental results was satisfactory and information about the ratio between longitudinal and transversal masses of the electrons responsible for the conduction has been obtained.

An upper limit for that ratio has been determined and agrees with those obtained by other researchers, but not with the cyclotronic resonance experimentations.

For *p*-germanium the comparison between theoretical and experimental data is only partially possible. Discussion of the experimental results have been carried out by means of an approximate theory, based on the hypothesis that constant energy surfaces of valence band are of spherical form. Such hypothesis did not appear to be sufficiently correct.

The etching process for cleaning of the surfaces of germanium monocrystals has been studied in the same laboratory. Different methods of etching have been examined, some of them having a preferential effect on certain crystallographic orientations. Each etching process has been carried out over different faces of the crystal and the control was achieved by microscopic observation and resistivity measurement with the method of the four end-pointed tungsten-probe.

The laboratory has a wide research program in the field of the semiconductor crystals.

At C.I.S.E. laboratories of Milano, germanium monocrystals have been bombarded with α particles of the $^{210}P_0$ (5,3 Mev.). Conductivity measurements carried out after different times of radiation have confirmed the germanium transformation from *n* to *p*. From the initial slope of the curve giving the relationship between the conductivity and the integrated flux of the α particles, it is possible to obtain the number of negative carriers that are removed from the conduction band by each α particle. Measurements between -78 and $+65^{\circ}$ C indicate that this number does not depend on radiation temperature and is equal to 79 ± 5 electrons/α.

It has also been found that the radiation produces a spectrum of levels more complicated than the one produced by electron

bombardment and this has been put in connection with the possible formation of complex defects (interstitial clusters and vacancies) while bombardment with electrons produces mainly isolated couples of intersticies and vacancies.

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Discharge through gases

At the Istituto di Fisica dell'Università di Bologna the relaxation oscillations in a circuit containing a gas tube in parallel with a condenser have been studied, the circuit being fed by a constant voltage generator through a series resistance. By varying the generator voltage, the resistance and the capacitor, four different conditions of oscillation have been observed and they are : behaviour as counter ; intermittent discharges in Towsend's conditions ; discharges of first order ; discharges of second order. For each situation the start and stop conditions have been investigated and studied in connection with the particularities and characteristics of the tube.

At C.I.S.E. laboratories of Milano a systematic study of corona discharge mechanism between cylindrical electrodes in argon has been undertaken. An emission of ultraviolet photons in Townsend's avalanches has been discovered ; these photons are responsible of corona starting. The mechanism of production of such photon has been studied and from the examination of their average life it has been deduced that they come from excited A_2 molecules. Photoelectric action of these photons on the cathode was also

investigated. All these processes determine the starting of corona discharges, the oscillatory transient of which has been studied. The properties of these corona discharges can be used to realize a simple type of proportional counter.

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Japan

N° 203. — Report of the National Committee to Commission VII

M. Kotani, T. Okabe, T. Muto, G. M. Hatoyama, Y. Koike, Y. Asami

I. — Electron Emission

(T. Okabe, T. Muto)

Oxide coated cathode

Factors affecting the life of oxide coated cathodes were studied. The evaporation of barium oxide was considered as a main factor, and new cathode constructions were proposed for prolongation of the life (1, 2). As another factor, the poisoning by gases from the tube parts was thoroughly investigated (3, 4). The dissociation of barium oxide under electron bombardment was quantitatively studied with radioactive isotope (5). As for the interface layer, a convenient measuring apparatus of its resistance was developed and the relation between the interface layer resistance and the silicon contents of the sleeve was obtained (6). The resistance distribution of the oxide coating was also measured by the probe method, and high resistant part was found at the emitting surface (7). The sparking in the rectifying diode was investigated (8, 9). The effects of the current density and the core material upon the electron emission were also studied (10, 11). Velocity distributions of electrons emitted from various oxide cathodes were measured by retarding field method, and the results were explained qualitatively from the pore conduction mechanism (12). Other experiments supporting pore conduction mechanism, were also reported (13, 14).

The surfaces of the oxide coatings were successfully observed by an electron microscope. Silicon monoxide was used to take replica of the surface (15).

Cold Cathode

Cold cathodes using barium oxide were developed. Effect of gas discharge upon the cold cathode was studied, and the manufacturing process of practical cathode was reported (16, 17).

The nature and the manufacturing process of barium oxide were also reported (18). Total yield and energy distribution for electrons ejected from barium oxide by inert gas ions were calculated on the theory of Auger Neutralization (19).

Dispenser Cathode

Developmental works on L-cathode were reported. More than 10 000 hour life at the operating temperature 1000° C, and more than 7000 hour at 1100° C were obtained (20). Some modifications of L-cathode were also reported (21). A new cathode called « bariated tungsten emitter » was studied (22).

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II. — PHYSICS OF SEMICONDUCTORS

(George M. HATOYAMA)

(1) *Surface Phenomena*

Surface conduction, surface recombination velocity, and field effect on germanium surfaces are being studied at Electrotechnical Laboratory, Electrical Communication Laboratory, Kobayashi Institute of Physics and Tokyo Tsushin Kogyo Ltd. I. Nakada (1) (Kobayashi Inst. of Phys.) has studied the dependence of surface recombination, surface conductance, and contact potential on the ambient and has found that the ratio $\mu h/\mu e$ of mobilities in molybdenite is very small. M. Kikuchi (2) (ETL) has observed the change in φ_s when a germanium surface is kept in air after being etched, and also he has found the increase of relaxation time constant with the thickness of the oxide layer on germanium surface. M. Kikuchi and S. Iwata (3) (Tokyo-Tsushin) have observed that the maximum in surface recombination occurred for φ_s apart from the center of the forbidden band, and have thus concluded that the capture

cross sections of a trap for holes and electrons are different from each other.

It has been found (Iwata) that the surface recombination velocity increases when a mica sheet is just pressed on a surface of silicon.

Experiments on clean germanium surfaces are now going on at Hokkaido University. A. Kobayashi (4) has found that the surface state density of germanium increases to an order of $10^{12}/v$ cm^2 when the surface is made clean, in favor of assuming the existence of something like a Tamm-level.

Inhomogeneities of surface leakage current along the periphery of the alloyed germanium p-n junction have been studied by M. Kikuchi (ETL) (5). A small spot of light is thrown along the periphery of the junction and the dependence of the photocurrent on the voltage applied and on the light intensity is measured at every point on the periphery. The dependence of photocurrent on the applied voltage can be classified in two types, namely, ohmic and avalanche types.

(2) *Transistor Technique*

Etch pits on the surface of germanium are studied at Tokyo University by R. Hashiguchi and others. It is shown that on (100) and (111) surfaces the pits with their edges parallel to (110) directions appear preferably. Etch pits on (110) surfaces are rather hard to observe, but they show themselves clearly if the surface is bombarded with deuterons. Moreover, it has been found that the lifetime increases heavily by the bombardment with deuterons, thus showing the phenomenon of fictitious lifetime.

Use of Ga-Ge Alloy as the alloying material for germanium is studied (6) (Kikuchi, ETL) for the purpose of obtaining a planar junction and also high gamma. By the use of this alloy, the wetting of germanium surface happens for lower temperature than alloying and hence result into a planar junction. Moreover, the segregation constant for Ga is much larger than for In thus making the hole concentration in the p region higher.

P-$n(-p)$ hook diode is investigated by Iwata (Tokyo Tsushin) as a switching element. It is found that when some copper is introduced as acceptor impurities the operating properties of the hook is stabilized.

Properties of evaporated alloy germanium diode are investigated for uses as photo devices by Takeya and others (Broadcast Corporation Research Institute). Spectral and other characteristics are studied.

It is found (7) (Kikuchi, ETL) that the existence of dislocations on germanium surface is effective for leaching out the thermal acceptors from the germanium. Thus, samples with smaller density of thermal acceptors are prepared by lapping the surface before heat-treatment.

The effect of an electric field during the process of zone melting is studied by Watanabe and Nishizawa (Tohoku University). They have found the possibility of controlling the impurity content in this way.

(3) *Noise in semiconductors*

Noise in transistors and its relation to other properties are studied by T. Niimi and R. Shikama (8) (Electrical Communication Laboratory), and by T. Yajima (9) (Broadcast Corporation Laboratory). It is found that a deteriorated transistor with large noise and high I_{co} recovers its original character when the surface is etched again. Also, the correlation between noise and I_{co} is found in other experiments.

Yajima (BCL) (10) has analysed the relation between α and noise in germanium tetrode and concluded that the partition noise is predominant. Also it is found that there are correlations between surface recombination velocity and the noise.

T. Inuishi (11) (Osaka University) finds that it is the leakage but not the saturation component of the reverse current in germanium junction diodes which is responsible for the $1/f$ noise.

(4) *Band structure of semiconductors*

M. Shibuya (ETL) has calculated the current versus voltage relation in semiconductors with spheroidal energy surfaces and has concluded that there will be a difference between the directions of the current and the electric field vectors at high electric fields. Actually, such effect has been found by him and W. Sasaki (12) observing the transverse electric field when the electrons in germanium are made « hot » by passing large currents impulsively.

Sasaki has also observed the Hall and magnetoresistive properties of hot electrons in germanium, which is different from the ordinary properties of electrons in Ge.

An acousto-electric effect in germanium is also found (13). A progressive, ultrasonic wave of intensity about 10 W/cm^2 is passed through an *n*-type germanium rod. An electromotive force of the order of 1 microvolt/cm is observed. The result is explained as a « phonon drag » phenomenon, and is compared with the expectations from the thermoelectric data.

The properties of germanium and indium antimonide at low temperatures are also studied (Sasaki, ETL ; Y. Kanai, ECL). It is shown that these materials with proper amount of impurities show a negative magnetoresistive effect.

(5) *Researches on other kinds of semiconductors*

Researches on the IV-VI compounds are going on. T. Okada and A. Okazaki (14) (Kyushu University) are studying systematically the properties of these compounds both from structural and electrical sides.

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III. — Microwave electronics

(Y. Koike)

Remarkable proposals and works in the field of microwave vacuum electronics will only be reported here, because some recent developments in usual klystrons, traveling wave tubes, magnetrons and mm wave devices were already reported at the International Congress of Microwave Tubes at Paris 1956.

(1) *Millimeter wave magnetrons*

Mito, Aoi and others proposed a concentric TE_{nio} mode magnetron without slots (1) and a spacial harmonic magnetron with a

few slots (2), in order to overcome the difficulties and delicacies in fabricating multicavity magnetrons in mm wave region. Theoretical investigations were carried out, and they are now studying experimentally such newer magnetrons.

(2) *Klystrons*

Fuzisawa (3) proposed a new type of klystron. The basic structure of this klystron is that the cavity is in the form of a wave guide with a tuning plunger and in the middle of the cavity two parallel planes with multi-interaction slits on both sides are placed and through which a rectangular thin strip beam is passed.

The operating principle is something like a floating drift tube klystron, and under the appropriate condition of electron transit time between two adjoining slits, optimum bunching will be accomplished so as to oscillate efficiently.

This principle permits simpler construction, wider tuning range and closer beam coupling and is promissing to generate mm waves.

(3) *Traveling wave tubes*

By using a helical wire having large diameter, when one turn length is longer than the applied wave length, it will act as a foreward slow wave element and when one turn length is shorter, it will act as a backward wave element.

Oyama (4) analized the spacial harmonic characteristics of such a large diameter helix theoretically and studied the foreward amplifier experimentally. In experiments, the helix of 25 mm diameter and 185 mm length was used at the frequency 3615 Mc/s and two electron beams, each 1.5 mA, were located just outside the helix. The overall gain was about 20 db. Further experiments in 24 GC are now going on.

(4) *Frequency multipliers*

For the purpose of generating mm waves by the principle of frequency multiplication, two types of traveling wave tube were developed.

Morita (5) used a helix type traveling wave multiplier which has the input modulating gap similar to the usual klystron buncher.

Preliminary experiments at the wave length of 7 cm showed that the 6th harmonics was produced successfully.

Another method was proposed by Matsuo (6), he used a disc-loaded wave-guide as the slow wave element and studied theoretically the possibility of harmonics production in mm wave region.

A new interesting method was proposed by Koike (7). The principle of the new tube named Peniotron is that the bunched electron beam injected in the uniform magnetic field makes circular orbits on which electron bunches of any number associated with the cyclotron frequency can be arranged to drive the output cavity or wave guide located at the osculating point of orbits. This tube then act as a frequency multiplier with low output impedance and high efficiency.

The possibility of producing submillimeter waves was resulted by theoretical investigations. Experiments are now going on.

Another high power frequency multiplier utilizing microwave discharge in low pressure gases was also reported by Uenohara (8).

A discharge cavity provided with a gap composed of two cylindrical posts and exposed in the low pressure atmosphere, between 10^{-1} —1 mm Hg, was inserted in the wave guide excited by the output of 3000 Mc/s continuous wave magnetron.

After the discharge was started, the harmonic output power was picked up through the high pass filter, and strong 2nd, 3rd and 4th harmonic components were detected, although the harmonic components of the incident wave itself could scarcely be measured.

The maximum output power of 10 mW, 9000 Mc/s was obtained with the incident power 20 W, 3000 Mc/s.

The mechanism of this phenomenon is not still clarified.

(5) *Plasma Oscillation*

Koike (9) discussed the possibility of microwave generation and amplification by using a d.c. electron beam penetrating through a thin plasma layer.

The electron plasma oscillation will be excited by the d.c. energy of the incident electron beam which passes through the plasma

layer perpendicularly, and in turn this oscillation will modulate the d.c. electron beam, therefore, if the plasma density is high enough, the microwave oscillation will propagate along the beam and will be amplified by some known method.

The possibility was verified by experiments. He used a special hot cathode mercury arc tube which was designed so as to make the thin plasma layer in the main arc path. The microwave output was detected by the probe along the beam. Results show the detected output frequency of 2000 Mc/s is slightly higher than the plasma frequency calculated from the observed plasma temperature and density.

(6) *Noise in electron beams*

The following two papers which will be presented and discussed at the meeting of Commission VII at Boulder, will be abstracted supplementally.

1. *Experiments on Microwave Noise in Electron Beams*, by Dr. Masaharu Okochi (Tokyo Institute of Technology).

It has been found that the noise output picked up by a cavity resonated at 4000 Mc/s increases with the intensity of the beam current.

Experiments were performed under the completely space charge limited condition, and a special case was taken to avoid the partition noise. The results show a definite disagreement with Rack-Lewellyn's theory, which will be discussed at the meeting.

2. *Theory of Microwave Noise at the Virtual Cathode*, by Dr. Jiro Koyama (Electrical Communication Laboratory).

Formulas for the current noise and velocity noise at the virtual cathode were derived, taking account of the effect of the transit time between the virtual cathode and the cathode and of the returning electrons.

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4. J. Oyama. — *Report n°* 747. *A.J.M.E.E.*, 1957.

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6. K. Matsuo, M. Hara. — *Report n° 760. A.J.M.E.E.*, 1957.
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Abbreviation : *A.J.M.E.E.* : *Annual Joint Meeting of 4 Institutes in the Field of Electrical Engineering of Japan.*

IV. — Gaseous Electronics

(Y. Asami)

Fluctuation and Oscillation in Gas Discharges

The current fluctuation and oscillation in fluorescent lamps have hitherto been studied by Matsuda, Otani, Ishidani, Miura and others.

Matsuda and others (1) especially studied the reignition oscillation in cathode oscillations. They pointed out that the wave form of the reignition oscillation was that of irregular relaxation oscillation, and that the regular relaxation oscillation appearing after the reignition oscillation was one of the twin oscillations and was different from such a reignition oscillation by reason that it was observed not only in an a.c. discharge but in a d.c. discharge.

Miura (2) found the same oscillation as the reignition one in the latter part of the half cycle of discharge, in addition to various oscillations hitherto observed in fluorescent lamps. He confirmed that the latter of twin oscillations found by Steele (3) was observed in the discharge lacking a positive column and was hard to generate, easy to disappear. He also found that the twin oscillations were the relaxation ones, the frequency of which increased with increase of the lamp current. Though Miura was of the same opinion with Culp as to the cause of anode oscillations, he quantitatively clarified the conditions that the oscillations appeared when the anode fall slightly exceeded the ionization potential of Hg.

Asami, Matsumoto and Nishitsuji (5) studied the fluctuation and oscillation appeared in d.c. discharges in various types of tubes, TY-65G, TY-66G, HV-967A, HX-966, tunger tubes, experimentally manufactured discharge tubes of a diode, a triode and a pentode. They recorded the terminal voltage and the wave

form, and investigated the effects of a discharging current, of an impressed magnetic field and of external circuits such as a parallel capacitance, a series inductance and under varied grid bias voltages. They further clarified that the wave forms were observed in various types of oscillations such as a relaxation oscillation, an irregular relaxation oscillation, a sinusoidal oscillation and others, and that such oscillations and fluctuations could be controled through the adjustment of internal and external conditions.

Takayama and others (6) studied the oscillations and rotations of a ball-of-fire mode which appeared in the diode discharge tube of a cylindrical type with a hot cathode. They found that the ball rotated backwards under the weak cross magnetic field and forewards under the strong one, and that the number of rotations was proportional to the intensity of the magnetic field.

Takayama (7) studied the discharges of an anode glow and a ball-of-fire mode by the use of experimentally manufactured tubes, diode discharge tubes of a cylindrical and a parallel electrode type with Ar, Kr, Xe of several mm Hg. In the observation of anode oscillations, he found the oscillation with frequency of 1 to 10 Mc/s which superposed the falling part of the fluctuating current was caused by the fluctuation of the ball. Moreover, he confirmed that the oscillation appeared in such gases only which had a maximum value in the velocity versus number of collision curves, and it did not appear in case of the gases, He, H_2, Ne, Hg and so on. He therefore concluded that the oscillation was to be the Ramsauer-Townsend oscillation.

Yoshimoto and Sato (8) especially observed the light intensity wave in the study of the moving striation in a glow discharge by the use of a hot cathode discharge tube with Ar and Hg. By the assumption that the light intensity was equal to the electric field intensity multiplied by the electron density, he thought that the electric field appeared as a positive wave accompanying the space charge wave by positive ions, the electron density on the other hand as a negative wave, and accordingly various modes of the moving striation appeared because of relative magnitudes of both waves. He finally came to the conclusion that the moving striation, supposed to be an apparent phenomenon of waves, was not the motion by the space charge density.

Kojima, Kato and Hagiwara (9) detected the plasma oscillation

in the d.c. discharge of a low gas pressure by the use of a hot cathode discharge tube with Hg gas, employing the small antenna connected to a super-regenerative receiver. The frequencies were observed from 680 to 1000 Mc/s in the range of the discharging current between 15 to 80 mA. It was noticeable that the strong plasma oscillation was found in the positive column of the discharge tube.

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Netherlands

N° 226. — Report of the National Committee on the activity in Radio-electronics 1954 - 1955 - 1956

I. — The physics of the cathode

Properties of oxide cathodes that are not well understood have been studied, such as the velocity distribution of the emitted

electrons under puls conditions (1), the evaporation (2, 3) and the conduction (4) of the alkaline-earth oxides.

Deviations in the calculation of the electron emission with Langmuir's formula, are investigated by Walraven (5).

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II. — THE PHYSICS OF SEMI-CONDUCTING DEVICES FOR RADIO APPLICATION

A number of papers which are partly theoretical (3, 5, 6, 8, 9, 14, 16, 17) and partly experimental (1, 2, 4, 7, 10, 11, 12, 13, 15) in the physical or technological field demonstrates the present scientific and industrial interest in the properties of semi-conducting materials.

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2. B. H. SCHULTZ. — Analysis of the decay of photoconductance in germanium. *Philips Research Reports*, Vol. 90, pp. 337-348 (1955).
3. J. C. VAN VESSEM. — The theory and construction of germanium diodes. *Philips Technical Review*. Vol. 15, pp. 213-224 (308 erratum) (1955).
4. J. JAGER. — The application of pointcontact germanium diodes. *Philips Technical Review*, Vol. 16, pp. 225-232 (1955).
5. F. H. STIELTJES, L. J. TUMMERS. — Simple theory of the junction transistor. *Philips Technical Review*. Vol. 17, pp. 233-246 (1955).
6. F. H. STIELTJES, L. J. TUMMERS. — Behaviour of the transistor at high current densities. *Philips Technical Review*. Vol. 18, pp. 61-68 (1956).

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8. R. GEVERS. — The transport of injected electrons and holes in a semiconductor. *Physica*, Vol. 21, pp. 888-896 (1955).

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11. K. M. VAN VLIET, J. BLOK. — Electronic noise in photo-conducting insulators. *Physica*, Vol. 22, pp. 525-540 (1956).

12. A. VAN WIERINGEN, N. WARMOLTZ. — On the permeation of hydrogen and helium in single-crystal silicon and germanium at elevated temperatures. *Physica*, Vol. 22, pp. 849-865 (1956).

13. A. VAN ITTERBEEK, W. DUCHATEAU. — Further measurements on the magnetic susceptibility of germanium down to liquid-helium tempetures. *Physica*, Vol. 22, pp. 649-656 (1956).

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III. — THE SOURCE AND NATURE OF NOISE

For many years in the past noise has been a subject of research in the Netherlands. In the last three years a few studies are published on theoretical noise analysis (1, 2, 4) and on measurements of noise and on investigations in the source of noise (3, 5).

1. A. G. Th. BECKING, H. GROENDIJK, K. S. KNOL. — The noise factor of four-terminal networks. *Philips Research Reports*. Vol. 10, pp. 349-357, (1955).

2. J. VAN SLOOTEN. — Oscillations and noise. *Philips Research Reports*, Vol. 11, pp. 19-26 (1956).

3. F. L. H. M. STUMPERS, N. VAN HURCK. — An automatic noise-figure indicator (brief report). *Philips Technical Review*, Vol. 18, pp. 141-144 (1956).

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IV. — OSCILLATION PHENOMENA IN GAS DISCHARGES

Measurements of the refractive indices of gases in the microwave region are published by Heineken and Bruin (1), Kok studied gasfilled triodes and communicated the results in two papers (3, 4).

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2. N. G. VAN KAMPEN. — On the theory of stationary waves in plasmas. *Physica*. Vol. 21, pp. 949-963 (1955).

3. J. A. KOK. — Experiments with gasfilled triodes. *Applied Scientific Research*. Vol. B5, pp. 445-453 (1955-56).

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V. — MAGNETISM

A certain number of papers deals with the properties of the magnetic materials in general (19) and of special magnetic materials such as ferrites (2, 10, 15), ferroxcube (4, 12, 14), ferroxplana (13), ferroxdure (11) and ticonal (18). There are also studies published of an investigation of the conducting properties (16, 17) and the influence of temperature (20) of magnetic materials and others that deals with antiferromagnetics (6, 8).

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2. K. F. NIESSEN. — Spontaneous magnetization as a function of temperature for mixed crystals of ferrites with several Curie temperatures. *Philips Research Reports*, Vol. 9, pp. 197-208 (1954).

3. E. W. GORTER. — Saturation magnetization and crystal chemistry of ferrimagnetic oxides. *Philips Research Reports*, Vol. 9, pp. 295-365, pp. 403-443 (1954).

4. F. K. DU PRÉ. — On the microwave Cotton-Mouton effect in ferroxcube. *Philips Research Reports*, Vol. 10, pp. 1-10 (1955).

5. J. SMIT, H. G. BELJERS. — Ferromagnetic resonance absorption in $BaFe_{12}O_{19}$, a highly anisotropic crystal. *Philips Research Reports*, Vol. 10, pp. 113-130 (1955).

6. K. F. NIESSEN. — Magnetic anisotropy and Van Vleck's relation for antiferromagnetics. *Philips Research Reports*, Vol. 10, pp. 131-140 (1955).

7. K. F. NIESSEN. — Condition for resonance in a nearly compensated ferrimagnetic. *Philips Research Reports*, Vol. 11, pp. 57-65 (1956).

8. K. F. NIESSEN. — Spontaneous magnetization and magnetic susceptibilities of an antiferromagnetic with foreign ions in only one sublattice. *Philips Research Reports*, Vol. 11, pp. 172-182 (1956).

9. F. K. LOTGERING. — On the ferrimagnetism of some sulphides and oxides. *Philips Research Reports*, Vol. 11, pp. 190-249, pp. 337-350, (1956).

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11. A. L. STUIJTS, G. W. RATHENAU, G. H. WEBER. — Ferroxdure II and III, anisotropic permanent-magnet materials. *Philips Technical Review*, Vol. 16, pp. 141-147 (1954).

12. H. G. BELJERS. — Amplitude modulation of centimetre waves by means of ferroxcube. *Philips Technical Review*, Vol. 18, pp. 82-86 (1956).

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17. G. H. JONKER. — Magnetic compounds with perovskite structure, IV. Conducting and non-conducting compounds. *Physica*, Vol. 22, pp. 707-722 (1956).

18. D. A. LOCKHORST, A. VAN ITTERBEEK, G. J. VAN DEN BERG. — Measurements on the coercive force of « Ticonal » down to liquid-helium temperatures. *Applied Scientific Research*, Vol. B3, pp. 451-455 (1954).

19. L. NÉEL. — Remarques sur la théorie des propriétés magnétiques des substances dures. *Applied Scientific Research*, Vol. B4, pp. 13-24 (1954-55).

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VI. — Tubes

In a country with tube factories publications can be expected relating to the special use or the design of tubes.

There are studies on tubes for ultra short waves such as magnetrons (1), klystrons (3, 8, 9) and dynatrons (19) ; other publications are dealing with cathoderaytubes (4, 5, 10) from which nrs 3, 6, 7, 14 are discussing cameratubes. Photoelectric tubes are dealt with in the nrs 11, 15, 16, 17 and 18. No 12 discusses fast counter circuits with decade scaler tubes and no 13 cold-cathode trigger tubes.

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VII. — MISCELLANEOUS

From the diversity of subjects in the papers in this section there are five on secondary emission (1, 2, 5, 7, 8), two dealing with the dielectric constant (9, 11), two on manometers (3, 12) and two on skin effect (6, 10).

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Poland

N° 208. — Report of the National Committee to Commission VII

1. — Semiconductors

Laboratory of Electronics, the Institute of Basic Technical Problems, the Polish Academy of Sciences, Warsaw.

1. The research conducted was mainly on method of obtaining germanium and silicon with the required characteristics (1, 4) and on determining the conditions influencing the properties of semiconductor elements (5, 9). A study was also made of the properties of thermistor materials (10).

The Institute of the Radiotechnics of the Warsaw Polytechnic School.

2. A method was worked out for obtaining antimony of a extremely high degree of purity (11) and research was carried out on the lifetime of minority carriers in germanium (12).

2. — Vacuum Electronics

The Institute of the Radiotechnics of the Warsaw Polytechnic School.

3. Studies were made on the theory and simplified methods of studying the influence of space charge in the diode (13, 14) and an investigation was made into the properties of the electron emission of thoria (15).

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Sweden

N° 219. — Report of the National Committee to Commission VII

(Henry WALLMAN)

This report is based on the papers presented at RVK-57, the radio-scientific conference referred to in the introduction.

Prof. O. E. H. Rydbeck, Chalmers University of Technology, Göteborg, has developed an application of the telegraph equation to the coupling between a microwave resonator and an electron beam, the coupling being used for purposes of modulation or demodulation.

Prof. Rydbeck has in addition studied the concept of modes in plasma waves in an electron beam with non-homogeneous cross-section.

Mr. L. Torstensson, Swedish Electron-Tube Company, Stockholm, has studied klystrons designed for good modulation properties. Investigations have been carried out on the theoretical conditions for a klystron permitting good linearity of modulation, the work also includes a study of the influence of the load and a study of methods for designing reflex klystrons having good modulation linearity.

Mr. B. Adgur of the Royal Institute of Technology, Stockholm, has devoted several years to a theoretical and experimental study of the strophotron and more generally of the energy exchange between electrons and microwave fields. This work has recently been presented in a doctor's thesis.

Other experimental work on strophotrons has been carried out by Mrs. H. Häggblom and S. Tomner, Swedish Electron-Tube Company, Stockholm, at 1000, 2000, 3000 and 5000 Mc/s. Special attention has been devoted to modulation characteristics.

Prof. H. Alfvén, Royal Institute of Technology, Stockholm, has investigated the motion of electrons in magnetic quadripole fields of special type. The electron trajectories form a meander pattern, and lead to the development of a microwave « meander » tube.

Experiments on meander tubes have been carried out by

Mr. T. Hanaas of the Royal Institute of Technology, who has built a number of 10 cm oscillators of this type yielding about 30 W.

Mr. E. Aström, also of the Royal Institute of Technology, has investigated the questions of how the magnetic field in a meander tube should be fashioned for best results.

Mr. S. Olving, Chalmers University of Technology, Göteborg, has studied the representation of the complex propagation constants in a travelling-wave tube. These constants display a complicated dependance on the tube parameters, such as the current density, the radius and velocity of the electron beam, the radius and pitch of the helix and the frequency. This study is, in contrast with simpler theories for travelling-wave tubes, not restricted to the specialness of low current-density. Mr. Olving has also developed an approximate phase-relation for plasma waves in an electron tube with continuously variable longitudinal electron velocity.

Mr. K. N. Nygård, Chalmers University of Technology, has carried out a theoretical study of current nodes in plasma waves. Experimental measurements of plasma waves in an electron beam in a voltage step have been carried out by Mr. O. Steinstö, also of Chalmers University of Technology.

In connection with the plasma resonator, Mr. A. Dattner, Royal Institute of Technology, Stockholm, has investigated both theoretically and experimentally the resonance between an electromagnetic wave and an oscillation in a plasma column. Measurements of noise and the influence of external magnetic fields on a plasma resonator have also been carried out.

Work at Electronics Laboratory, Chalmers University of Technology

The studies of interaction between electron streams and electromagnetic waves have continued. Theoretical studies of the reflection of electro-magnetic waves from an electron stream in the presence of an arbitrary focussing magnetic field have been completed. So has the theoretical study of the interaction of crossing electron streams without neglect of Lorentz terms and relativistic corrections. A study has been made of the behaviour electron-spin oscillators at microwaves.

The amplification of travelling wave tubes at high current densities has been studied theoretically. The « telegraph equation » of the electron stream has been applied to the study of coupling between electron beams and cavity resonators, and to the coupling between space charge waves and electro-magnetic waves in resonant plasmas (with application to the radiation from plasma oscillators).

The experimental studies of interaction (at microwaves) between crossing electron streams continue. A long series of experimental investigations at 10 cm wavelength concerning space charge waves in finite velocity gaps has been concluded.

The problem of the stability of the proposed extra terrestrial auroral current ring has been discussed and surveyed theoretically.

A new type of electron tube, the Rotatron, has been developed. This tube is especially designed for frequency shifts (with or without simultaneous multiplication). The frequency shift operation is practically ideal. It is planned to use tubes of this type in the institutes radioastronomical hydrogen line recorder. Tubes of this type should be useful in multichannel radio frequency equipment.

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9. O. Steinstö. — An experimental investigation of space charge waves in a finite velocity gap (in course of publication).

10. S. Olving. — Space charge waves in an electron beam with variable velocity (in course of publication).

Summary. — A method is developed which makes it possible to study the behaviour of space charge waves along an electron beam with finite as well as infinite diameter and variable axial drift velocity. The finiteness of the beam radius is taken into account by introducing a reduction factor for the plasma frequency. The method is especially valuable when the beam velocity varies in such a way that only numerical analysis can lead to a description of the properties of the waves.

11. S. Olving. — Representation of the complex propagation constants of a travelling wave tube on a Smith diagram (in course of publication).

12. O. E. H. Rydbeck. — On the space charge wave-length of perpendicularly inhomogeneous electron streams (in course of publication).

Summary. — In connexion with experimental studies at the Research Laboratory of Electronics of the space charge wave properties of inhomogeneous electron streams it has become desirable to investigate the influence of the transverse shape of the stream (or the beam) upon the plasma wavelengths of the various space charge wave modes.

The present communication deals with two streams which can be studies by exact methods ; the exponential, plane stream and the circular stream with a current density distribution (versus radius φ) of the type $i_0 = i_0(a)a/\varphi$. It is shown that in both cases, as expected, the space wave-lengths can be computed by fairly simple methods for the higher modes, and that they can be related (by a fairly simple expression) to the mean electron density of the stream. For the lower modes, however, matters become much more complicated and one must resort to the exact wave functions for a precise determination of the eigenvalues. The general variation of the plasma wave-lengths, however, with the effective beam (or tube) radius is much the same as for the homogeneous beam, although the scale factor may be quite different.

Finally the application of phase integral methods to the study of the higher-mode properties of any beam (with monotonically decreasing electron density) is demonstrated as a typical example of the influence of the parameters involved.

The present study is part of a research program supported by the Swedish Research Board for the technical sciences.

13. O. E. H. Rydbeck. — Electromagnetic wave reflexion and space charge wave propagation in electron streams (with applications to the ionosphere and the solar corona) (in course of publication).

14. O. E. H. Rydbeck. — The « telegraph » equation of the electron stream, with applications (in course of publication).

15. O. E. H. Rydbeck. — The Rotatron, a new frequency shift and multiplier tube (in course of publication).

Switzerland

N° 144. — Report of the National Committee to Commission VII

Dr. SCHAETTI

1. — PHYSICAL PROPERTIES OF CATHODES

In the Department of Applied Physics of the Swiss Federal Institute of Technology (ETH) (*) the investigations of photoelectric cathodes were continued. The most important new tube is a photomultiplier-tube with a Cs-Sb-Photocathode of 26 cm of useful diameter. This tube is designed for application in nuclear physics (1,2).

2. — PHYSICAL PROPERTIES OF SEMICONDUCTORS

Several laboratories of the ETH and of some universities continued their activity in the field of semiconductors, especially : the Physical Department of the ETH (prof. Busch and co-workers), the Department of Applied Physics of the ETH (Dr. Baumgartner), the Department of Electrical Engineering of the ETH (Prof. Strutt and co-workers), the Department of Applied Physics of the University of Basle (Prof. Baldinger), the Physical Department of the University of Neuchâtel (Prof. Rossel).

Beside these institutes an activity more and more important is to be pointed out in the industrial laboratories of Switzerland.

The investigations of prof. Busch and his collaborators relate to the following intermetallic compounds : Ca_2Si, Ca_2Rb, $ZnSb_2$, $MgSb_2$, Insb, Mg_2Ge, Mg_2Sn, Mg_2Pg. They extend to thermoelectric tension, thermic conductibility, magnetic characteristics, etc.... A study is treating the question of the determination of the characteristics of not degenerated semiconductors by electric measurements (3, 17). After some investigations in the field of photoconductors, studies have been undertaken on semiconductors.

At the Department of Applied Physics of the ETH (Dr. Baumgartner). The question of noise of the current in semiconductors has been discussed (18).

At the Department of Applied Physics of the University of Basle research is going on, treating several questions on transistors

(*) Eidgenössische Technische Hochschule.

(Prof. Baldinger see report Commission VI (19, 21). The application of these elements of construction has been also studied on the Department of Electrical Engineering of the ETH (Prof. Strutt) (29, 24).

3. — Origin and nature of noise in electron-beams

In this field M. Haffter, of the Department of High Frequencies of the ETH (25) has issued a paper « Ueber das Rauschen von Elektronenstrahlen ». The squares of the fluctuations of the current along a cylindrical electron-beam are treated as the solution of a marginal problem of the Maxwell-Lorentz theory. The calculation of this problem shows that the minima of the stationary wave are different from zero, by principle, and that it does not exist an exact periodicity for the extreme values. The result has been tested and confirmed by experiments.

M. Weibel has studied the travelling wave-tubes at the same department of the ETH (26).

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United Kingdom

N° 138. — Report of the National Committee to Commission VII

by C. W. Oatley

1. — Introduction

The field covered by Commission VII is so large and the number of original papers within this field that have been published during the past three years is so great that a general review cannot do more than indicate the main lines along which work has proceeded. References to specific pieces of research work cannot normally be made, but the classified list of papers should remedy this defect.

2. — Thermionic Emission, Secondary Emission and Field Emission

Numerous investigations of oxide-coated cathodes, including the newer dispenser cathodes, have been reported and attention has also been paid to the emission from hot cathodes in gaseous discharges. There has also been a good deal of work on field emission and electrical breakdown under vacuum conditions.

Progress in elucidating the phenomena of secondary emission has been chiefly on the theoretical side, though there has been an experimental study of the liberation of electrons from metal surfaces by low-energy ions.

3. — Electrical Conduction in Gases

There have been several investigations of basic ionization phenomena, including measurements of ionization and dissociation by electron impact, charge transfer and the detachment of electrons from negative ions.

Possible applications in connection with thermonuclear reactions have led to a number of studies of high-current gas discharges and the limitations to which they are likely to be subject. Several measurements on such discharges have also been made from other points of view.

Other investigations have been concerned with the technique of probe measurements, with the high-frequency properties of gas discharges, with sparks, with electrodeless discharges, with moving striations and with the phenomena occurring at contacts when a current is interrupted. The use of discharge tubes in microwave switches has also been studied.

4. — Semiconductors-Germanium and Silicon

As in other countries, the period under review has been marked by a shift of emphasis from point-contact devices to junction devices. Nevertheless, interest in point-contact devices remains and several papers have been published on the complex phenomena which they involve.

The search for rectifiers and transistors to operate at high ambient temperatures has led to increased interest in silicon and a great deal of effort has been devoted to the purification and the preparation of single crystals of this material. Another line of attack on the high-temperature problem has been the construction of germanium transistors in which the density of minority carriers is kept low by applying an electric field to sweep them aside.

New techniques have been devised for measuring the various properties of silicon and germanium and a great many measurements of this kind have been reported. In particular, a good deal of attention has been paid to measurements of lifetime in silicon, which have proved less straightforward than the corresponding measurements in germanium.

Surface properties of germanium have been studied and also the manner in which these properties can be modified by the application of a strong electric field. The application of an external electric field has also been found to reduce the absorption of microwave radiation in *n*-type germanium.

5. — Semiconductors — General

During the period under review considerable attention has been paid to new types of semiconducting material, particularly compounds of Group III and Group V elements. Many investigations of the properties and uses of indium antimonide have been reported and numerous other compounds have also been studied.

Several papers have been concerned with the effects of impurities in semiconductors or with the detection or removal of impurities. Progress has also been made with the theory of semiconductors.

Included in the bibliography of this section are a few papers on miscellaneous properties of solids other than semiconductors.

6. — Photoconductivity and Luminescence

Although much of the work carried out on luminescence has been of a technological nature, there have been some studies of luminescence in single crystals. Results of research work on electroluminescent phosphors have also been reported.

Measurements have been made on photoconductivity in a variety of materials.

7. — Vacuum Tube Devices

A great deal of effort has been directed towards some of the basic problems of electron optics. Methods of plotting electron trajectories have been studied and properties of electron lenses have been tabulated. Progress has been made in allowing for the presence of space charge and work has been done on electron beams in axial magnetic fields.

Several papers have been published on klystrons and on certain aspects of the theory of magnetrons, and considerable attention has been paid to factors affecting the lives of conventional triodes and pentodes.

8. — Fluctuation Noise

There have been several studies of a fundamental nature but most of the work in this subject has been directed towards the measurement or reduction of noise in electronic devices, particularly semi-conducting devices. Some results have also been published on noise from hot-cathode discharges in gases.

9. — Ferrites

There have been numerous investigations of the properties of ferrites and their applications to radio and electronic techniques. An international convention on ferrites was organized by the

Institution of Electrical Engineers during the latter part of 1956 and a list of papers presented to this convention by British authors is included in the bibliography.

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STANDLEY, K. J., PETERS, J. — Ferrimagnetic Resonance in a Magnesium-Manganese Ferrite.

TOMBS, N. C., WATKINS, J. — The Physical and Chemical Properties of some Nickel-Zinc Ferrite Compounds.

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U. S. A.

N° 304. — Report of the National Commission VII 1954-1957

(i) REPORT ON PROGRESS IN MICROWAVE ELECTRONICS

Possibly the most interesting development during this period is in the field of molecular oscillators. The first of these efforts was described in papers by :

J. P. GORDON, H. J. ZEIGER, C. H. TOWNES. — Molecular Microwave Oscillator and New Hyperfine Structure in a Microwave Spectrum of NH_3. *Phys. Rev.*, Vol. 95, p. 282, July, 1954.

J. P. GORDON, H. J. ZEIGER, C. H. TOWNES. — Maser, New Type of Microwave Amplifier Frequency Standard and Spectrometer. *Phys. Rev.*, Vol. 99, p. 1264, Aug., 1955.

These authors used a beam of ammonia molecules which was injected into a cavity after passing through a focusing device which separated two states of the molecule so that one had an excess population of the upper and lower state. This produces coherent radiation of the molecules, i.e., the cavity with the molecules behaves as an oscillator. A great deal of work has been done on this device in various places. One of its principal interests lies in the fact that it has an exceedingly low noise figure.

Other types of masers using electron spin resonance in a solid have been described by :

A. Honig, J. Combrisson. — *Phys. Rev.*, Vol. 102, p. 917, 1956.

N. Bloenbergen. — *Phys. Rev.*, Vol. 104, p. 324, 1956.

The latter one uses transitions between three states of a solid. An operating molecular oscillator of this type has been described in a paper by :

D. Scovel, G. Feher, H. Seidel. — *Phys. Rev.*, Vol. 105, p. 762, 1957.

The noise theory of such amplifiers has been given by :

M. Muller. — Noise in a Molecular Amplifier. *Phys. Rev.*, Vol. 106, p. 8, 1957.

R. V. Pound. — Spontaneous Emission and Noise Figure of Maser Amplifiers. *Annals of Physics*, Vol. 1, nº 1, paper 57.

Another method proposed, using ferromagnetic resonance in ferrites, is described in :

H. Suhl. — Proposal for Ferromagnetic Amplifier in the Microwave Range. *Phys. Rev.*, Vol. 106, p. 384, 1957.

In the area of more normal electron tubes, work on traveling wave devices has proceeded in various directions. Backward-wave oscillators, at a variety of power levels, bandwidths, and frequencies, have been built and the theory and understanding is greatly extended. A backward-wave oscillator, with a 5-1 tuning range, is described in a paper by :

J. W. Sullivan. — A Wide-Band Voltage Tunable Oscillator. *Proc. I.R.E.*, Vol. 42, p. 1658, Nov., 1954.

A backward-wave oscillator at about 3 millimeters using the helix is described in a paper by :

W. V. Christensen, D. A. Watkins. — Helix Millimeter Wave Tubes. *Proc. I.R.E.*, Vol. 43, p. 93, Jan., 1955.

Another tube, which went to even slightly higher frequencies using a ladder circuit, was described by :

A. Karp. — Traveling-Wave Tube Experiments in Millimeter Wavelengths with a New Easily Built Space Harmonic Circuit. *Proc. I.R.E.*, Vol. 43, p. 41, Jan., 1955.

The theory of backward-wave oscillators has been treated in a paper by :

R. W. Grow, D. A. Watkins. — Backward-Wave Oscillator Efficiency. *Proc. I.R.E.*, Vol. 43, p. 848, July, 1955.

A novel use of a backward-wave circuit as an amplifier by using two helices in cascade has been described by :

M. R. Currie, J. R. Whinnery. — The Cascade Backward-Wave Amplifier. A High Gain Voltage Tuned Filter for Microwaves. *Proc. I.R.E.*, Vol. 43, p. 1617, Nov., 1955.

In the field of traveling-wave tubes, there has been considerable work done on circuits and tubes suitable for higher powers than the conventional helix. One such circuit is described by :

M. Chodorow, E. L. Chu. — Cross-Wound Twin Helices for Traveling-Wave Tubes. *J. of Appl. Phys.*, Vol. 26, p. 33, Jan., 1955.

Another paper describes the first traveling-wave tube delivering power of the orders of hundreds of kilowatts :

M. Chodorow, E. J. Nalos. — Design of High-Power Traveling-Wave Tubes. *Proc. I.R.E.*, Vol. 44, p. 649, May, 1956.

In the theory of traveling-wave tubes fruitful applications have been made of an approach due to J. R. Pierce which considers coupling of two different modes of propagation. This is described in papers by :

J. R. Pierce. — The Wave Picture of Microwave Tubes. *Bell System Technical Journal.* Vol. 33, p. 1343, Nov., 1954.

H. Heffner. — A Coupled Mode Description of Beam Type Amplifiers. *Proc. I.R.E.*, Vol. 43, p. 210, Feb., 1955.

R. W. Gould. — A Coupled Mode Description of the Backward-Wave Oscillator and the Kompfner Dip Condition. *I.R.E. Trans. for Professional Groups on Electron Devices*, p. 37, Oct., 1955.

Considerable effort has been devoted, both experimentally and theoretically, to investigate the efficiency of traveling-wave tubes. Theoretical papers include :

P. K. Tien, L. R. Walker, V. M. Wolontis. — A Large Signal Theory of Traveling-Wave Amplifiers. *Proc. I.R.E.*, Vol. 43, p. 216, March, 1955.

J. E. Rowe. — A Large Signal Analysis of the Traveling-Wave Amplifier. *I.R.E. Trans. for Professional Groups on Electron Devices*, 1956.

Experimental work on the saturation characteristics of traveling-wave amplifiers has been reported by :

C. C. Cutler. — The Nature of Power Saturation and Traveling-Wave Tubes. *Bell System Technical Journal.* Vol. 35, nº 4, July, 1956.

J. J. Caldwell, O. L. Hoch. — Large Signal Behavior of High-Power Traveling-Wave Amplifiers. *Trans. for Professional Groups on Electron Devices,* Vol. 3, nº 1, Jan. 1956.

There has been a great increase in the understanding of the fundamental noise limitations of microwave amplifiers. There are a series of papers by various authors who show that under the assumption of certain plausible conditions at the cathode, all microwave amplifiers would have essentially the same noise figure, and that any possible design could only result in achieving the optimum noise figure, but could not go beyond it. These papers include the following :

J. R. Pierce. — A Theorem Concerning Noise in Electron Streams. *J. of Appl. Phys.*, Vol. 25, Aug., 1954, p. 931.

J. R. Pierce, W. E. Danielson. — Minimum Noise Figure of Traveling-Wave Tubes with Uniform Helices. *J. of Appl. Phys.*, Vol. 25, p. 1163, Sept., 1954.

H. A. Haus. — Limitations on the Noise Figure of Microwave Amplifiers of Beam Type. *I.R.E. Trans. for Professional Groups on Electron Devices*, p. 238, Dec., 1954.

H. A. Haus. — Noise in One Dimensional Electron Beams. *J. of Appl. Phys.*, Vol. 26, p. 560, May, 1955.

H. A. Haus, F. N. H. Robinson. — The Minimum Noise Figure in Microwave Beam Amplifiers. *Proc. I.R.E.*, Vol. 43, p. 981, Aug. 1955.

F. N. H. Robinson. — Microwave Shot Noise in Amplifiers. *I.R.E. Trans. for Professional Groups on Electron Devices*, nº 3, p. 128, July, 1956.

S. Bloom. — The Effect of Initial Noise Current Velocity Correlation on a Noise Figure of Traveling-Wave Tubes. *R.C.A. Review*, Vol. 16, p. 179, June, 1955.

As stated, all of these papers concern limiting noise figure under certain assumed conditions at the cathode. In particular, if there existed any correlation between velocity and current fluctuation at the cathode, the restrictions imposed by these papers would not apply. In order to determine this correlation, considerable effort has been devoted to investigating the behavior of the potential minimum. This has been reported in the following series of papers.

P. K. TIEN. — A Dip in the Minimum Noise Figure of Beam-Type Amplifiers, Letters to the Editors. *Proc. I.R.E.*, p. 938, Vol. 4, July, 1956.

P. K. TIEN, J. MOSHMAN. — Monte Carlo Calculation of Noise Near the Potential Minimum of a High Frequency Diode. *J. of Appl. Phys.*, Vol. 27, p. 1067, Sept., 1956.

A. E. SIEGMAN, D. A. WATKINS. — Potential Minimum Noise in the Microwave Diode. *I.R.E. Trans. for Professional Groups on Electron Devices*, p. 82, Jan., 1957.

J. R. WHINNERY. — Noise Phenomena in the Region of the Potential Minimum. *I.R.E. Trans. for Professional Groups on Electron Devices*, p. 221, Dec. 1954.

Extensive work on problems of electron beams continues in various areas. Some of the most interesting of these involves the behavior of hollow beams in a magnetic field. It was found by H. F. Webster that a hollow cylindrical electron beam in a magnetic field breaks up, so that as it proceeds along a drift tube the various portions each resemble what can best be described as spiral nebulae. This break-up, verified by others in both experiment and theoretical explanation in terms of the behavior of such a beam in a crossed electric and magnetic field, has been given in the following papers :

R. L. KYHL, H. F. WEBSTER. — Break Up of Hollow Cylindrical Electron Beams. *I.R.E. Trans. for Professional Groups on Electron Devices*, nº 4, p. 172, 1956.

J. R. PIERCE. — Instability of Hollow Beams. *I.R.E. Trans. for Professional Groups on Electron Devices*, Vol. 4, p. 183, 1956.

C. C. CUTLER. — Instability in Hollow and Strip Electron Beams. *J. of Appl. Phys.*, Vol. 27, p. 1028, 1956.

H. F. WEBSTER. — Break Up of Hollow Beams. *J. of Appl. Phys.*, Vol. 26, p. 1386, 1955.

Experiments on standard cylindrical beams (not hollow) have also indicated that these behave quite differently than the simple theory would indicate. There are effects to thermal velocities which have been treated in papers by :

C. C. CUTLER, M. E. HEINZ. — Thermovelocity Effects in Electron Guns. *Proc. I.R.E.*, Vol. 43, p. 307, 1955.

W. E. DANIELSON, J. L. ROSENTHELD, J. A. SALOOM. — *Bell System Technical Journal*. Vol. 25, p. 375, 1956.

In addition to these thermal velocities, there have been observed transverse velocities which are greater than can be explained

by these effects and which are presumably due to aberrations in the cathode-anode region. These are described in papers by :

C. C. Cutler, J. A. Saloom. — Pin Hole Camera Investigation of Electron Beams. *Proc. I.R.E.*, Vol. 43, p. 299, March, 1955.

A. Ashkin. — Electron Beam Analyzer. *J. of Appl. Phys.*, Vol. 28, p. 564, 1957.

(ii) Report on Progress in Noise

The problem on noise in electron beams will be covered in the section on microwave electronics, hence no references to this problem will be given here.

(*a*) *Noise in Vacuum Tubes, Noise Figure.* — Measurements on tubes with a wide grid pitch showed the effect of the inhomogeneity of the potential distribution in the cathode-grid region upon the correlated and the uncorrelated parts of the induced grid noise (1, 2). Talpey and Macnee have found indications that most of the uncorrelated part of the induced grid noise may come from electrons reflected elastically at the anode (3).

A very general treatment of noisy fourpoles was given by Rothe and Dahlke (4). Haus and Adler have given an extension of the noise figure definition by introducing the concepts of exchangeable power and exchangeable power gain, to cover the case of amplifiers with negative internal resistance (5).

(*b*) *Flicker Noise in Vacuum Tubes.* — Hannam and van der Ziel showed that large amounts of flicker noise may be generated in tubes that have a cathode-metal interface layer with an appreciable resistance. Zylstra and Alkemade found the same behavior in some vacuum photodiodes operating under space-charge limited conditions (7).

Johnson studied the influence of the cathode nickel alloy on flicker noise and found that magnesium nickel alloys gave relatively low noise (8).

Lindemann and van der Ziel (9) gave indication that in many cases the flicker noise is not space charge suppressed. They suggested a mechanism involving modulation of the current coming out of surface pores. Hannam found that electron bombardment of the anode may contribute to flicker noise (10) ;

his results seem to indicate that fluctuations in the rate of arrival or departure of atoms (or ions) from the surface determined the magnitude of the flicker noise.

Hannam (10) also studied the noise generated in the oxide coating. He found *1/f* noise at low frequencies and showed that at high frequencies a large amount of shot noise is generated in the pores of the coating when the temperature is such that pore conduction and grain conduction are comparable.

Measurements of EFP 60 tubes have shown that some flicker noise is associated with the secondary emission process, whereas the effect is negligible in photomultiplier tubes (11). Since the noise spectrum of a photomultiplier is flat down to 1 cycle and since equivalent saturated diode currents up to a few hundred amperes can be obtained without difficulty, the photomultiplier is attractive as a standard noise source (11, 12). Unfortunately the primary photocurrent and the multiplier gain are not constant, but show drift and hysteresis (12, 13), making frequent calibration necessary.

Lindemann and van der Ziel (14) have shown that the anomalous flicker effect in vacuum tubes with tungsten cathodes operated under space charge conditions is caused by the sudden release of about 10^4 ions which are trapped in the space charge cloud and which disappear by exponential decay with a life time of 1-50 μ sec.

Nielsen and van der Ziel published a paper on the design of a noise spectrum analyzer for rapid flicker noise measurements (15).

c) *Noise in Junction Diodes and Junction Transistors.* — The theory of shot noise in junction diodes and junction transistors is at present well understood and good agreement between theory and experiment has been obtained. The first solution of the problem held for a one-dimensional diffusion model and made use of a transmission line analogy, but the final results are so general that they must be independent of the model (16). Guggenbuehl and Strutt have generalized and modified these results by a heuristic approach (17). A corpuscular approach was given by Uhlir (18) and considerably extended and generalized by van der Ziel (19).

Experimental verification of the theory for transistors was reported by Guggenbuelh and Strutt (17), Nielsen (20), Hanson (21, 22), Hanson and van der Ziel (23) and Giacaletto (24) ; the latter's equivalent circuit, though somewhat different at first

look, is practically identical with the one used by the other investigators. Some deviations between theory and experiment may exist for frequencies close to the cut-off frequency (17, 22).

At audio frequencies the noise figure is determined partly by $1/f$ noise, and partly by shot noise; under favorable conditions rather low noise figures can be obtained (25). As a matter of fact, for audio frequencies and low source impedances the transistor has a much lower equivalent noise resistance than the vacuum tube. A few years ago, most transistors showed a large $1/f$ noise dependent upon the collector voltage; this effect could be greatly reduced by giving the collector practically zero bias (26). Modern transistors, however, have little collector noise, so that the choice of the collector voltage is unimportant. The $1/f$ noise in transistors seems to be associated with the emitter junction; its equivalent noise resistance decreases with decreasing emitter current (27). Junction transistors with low $1/f$ noise show great promise in wide-band amplifiers. Amakasu and Asano studied the temperature dependence of $1/f$ noise in *p-n-p* transistors (28).

Junction diode measurements by Champlin showed very good agreement with theory (29). Pearson and his co-workers found that the noise of a *p-n* junction photocell was shot noise down to 80 cycles if the device was kept in a dry atmosphere. In a humid atmosphere the noise was $1/f$ and was a factor 2×10^5 larger than shot noise at 100 cycles (30). Gianola found that the noise in a silicon photovoltaic cell was $1/f$ noise at low frequencies; the dependence of the noise on the illumination level could be explained from the equivalent circuit (31).

The $1/f$ spectrum of the noise in point contact diodes has been verified down to 6×10^{-5} cycles (32, 33); it was necessary to keep the device in a constant temperature bath to prevent temperature fluctuations.

(*d*) *Noise in Semiconducting Filaments.* — The noise generated in semiconductor filaments is of the $1/f$ type or of the shot noise (electronic noise) type. Progress has been made in the understanding of both types of noise.

The theory of shot noise is at present well understood; the effect is due to spontaneous fluctuations in the generation-recombination and in the trapping rates. Van Vliet has shown the equivalence of two methods of calculating the magnitude of such

fluctuations (34). A detailed study of shot noise in nearly intrinsic materials indicates very good agreement with theory (35). Shulmann has measured noise in CdS photoconducting single crystals (36). The results agree with theory ; the published measurements seem to show no *l/f* noise. Gebbie found evidence of noise due to trapping in *n*-type germanium samples at 200° K (37).

Simultaneous measurement of *l/f* noise and Hall effect noise shows that the *l/f* noise is due to majority carriers and allows to determine the spectrum of the fluctuating number Δn of carriers (38, 39, 40). It is found that $\overline{\Delta n^2}$ is of the order of $\bar{n}$. The results also indicate that in nearly intrinsic material the fluctuation Δn in the number of electrons is accompanied by fluctuation $\Delta p = -\Delta n$ in the number of holes.

The influence of plastic deformation on *l/f* noise has been studied (41, 42). The results indicate an increase in *l/f* noise.

The influence of ambient upon the *l/f* noise in germanium filaments has been studied (43). The generation of *l/f* noise has been associated with « slow » energy states associated with the surface structure and sensitive to the gaseous ambient (44, 45). A distribution in time constants $g(\tau)d\tau = \text{const}\ d\tau/\tau$ has been found experimentally ; this is the distribution needed to give *l/f* noise. Morrison, who has studied the same phenomena, has a different explanation for *l/f* noise (46, 47). McWhorter has given a detailed discussion of the relation between *l/f* noise and surface properties, and has put forward agreements in favor of the first explanation (48).

Work has been done on the photoconductive and noise properties of thin films (49, 50). Noise measurements in InSb samples have been reported (51, 52).

(*e*) *Gas Discharge Noise.* — A broad-band gas noise source makes use of a relaxation oscillation circuit using a gas tube. The noise is due to the randomness in the firing time of the tube (53, 54). The noise ratios are as high as 130 db at 5-20 Mc/s.

Work has been done on the detection of noise associated with plasma oscillations (55) in an arc discharge. The noise is generated at the cathode.

Simultaneous noise and impedance measurements have provided a better understanding of the noise mechanisms operating in

voltage regulator tubes (56, 57). A correlation has been found between the ion transit time in the cathode fall region and the frequency at which the impedance of the discharge changes from inductive to capacitive (58).

(*f*) *Miscellaneous Topics.* — The frequency spectrum of Barkhausen noise has been reported as being of the const/$(1 + \omega^2\tau^2)$ type (59).

The study of noise in van der Pol oscillators has been extended to the non-linear case (60).

(iii) Report on Progress in semiconductor Electronics

The band structure of germanium, silicon and other diamond lattice semiconductors has received much study. The « many valley » model has become accepted for germanium and silicon and its implications have been discussed (1). Cyclotron resonance has proven to be a powerful tool for studying the details of the energy band structure and determining accurate effective masses in germanium and silicon (2, 3, 4, 5, 6), germanium-silicon alloys (7) and diamond lattice compounds (8). Piezo resistance measurements have further confirmed the band structure (9, 10, 11, 21, 13).

The dependence of Hall coefficient on magnetic field has indicated the existence of holes in germanium of two different effective masses (14). Studies of the thermoelectric effect at low temperatures has demonstrated the interaction of charge carriers with phonons (15, 16).

The spin resonance of unionized donor centers has been observed in silicon and used to study the nature of the impurity centers (17, 18). Infra-red absorption techniques have also been extended to study impurity ionization (19, 20).

The classical electrical properties of germanium and silicon have been further delineated by studies of drift mobilities and Hall effect (21, 22, 23, 24, 25). The trapping of minority carriers in silicon has also been studied (26).

Much interest has centered on the electrical effects of lattice imperfections in germanium and silicon. The electrical effects of dislocations in germanium were reported 27, 28. Damage by electron bombardment (29, 30, 31, 32), gamma rays (33), and other energetic particles (34, 35) have been studied in germanium, silicon, and intermetallic semiconductors (36, 37).

The mechanism of electrical breakdown in *p-n* junctions of germanium and silicon has been investigated and determined to be caused by an avalanche multiplication process (38, 39, 40, 41, 42).

Radioactive recombination of minority carriers has been studied theoretically (44) and experimentally observed in germanium (45), silicon (46) and intermetallic compounds (47). Emission during *p-n* junction breakdown has also been reported (48, 49).

The diffusion of impurities in germanium (50) and silicon (51) was studied. Impurity diffusion was applied to the fabrication of solar batteries (52), power rectifiers (53), high frequency transistors (54, 55) and semiconductors switching devices (56.) The invention of a successful solar energy converter from silicon (52) gave rise to much consideration of photovoltaic cells as solar energy converters (57, 58, 59, 60).

Interest continued high in new diamond lattice semiconductors. Germanium-silicon alloys were studied (61, 62, 63). InSb (64, 65), GaSb (66, 67), AlSb (68) and InAs (69) received attention. A solar energy converter was made from GaAs (70).

Studies of noise in semiconductors were vigorously pursued over wide frequency ranges (71, 72). The *1/f* noise spectrum was extensively investigated (73, 74). Hall effect noise was also studied (75) as well as the increase in noise upon plastic deformation in germanium (76). An analysis of noise in diodes and transistors has also been presented (77).

The understanding of semiconductor surfaces was greatly advanced (78). Studies of field effect relaxation times led to the resolution of fast and slow states (79, 80, 81, 82). The development of bombardment techniques permitted studies on cleaner surfaces (83, 84) and theoretical studies predicted carrier mobilities in surface space charge layers (85). New field effect techniques permitted more intensive investigation of surface phenomena (86).

(iv) Report on Progress on the Physics of Thermionic Emitters

(*a*) *Introduction.* — Because of the vast amount of effort devoted to reaching a full understanding of the physics of cathodes, particularly semiconducting cathodes, it is impossible to summarize all recent work in detail in a brief report. An examination of the literature suggests that a major fraction of its content can be

summarized under a few headings. While such a summary can not encompass all of the work and may in fact distort its content somewhat because of the limited scope of the headings, this method of summarizing will be adopted in the present report for want of a better alternative. It is hoped that the appended bibliography will keep the various contributions in proper perspective.

(*b*) *Survey Papers.* — Three survey papers on thermionic emitters have appeared in the period 1954-1957. The most general is that of W. B. Nottingham which encompasses emission work up to the advent of the mobile donor theory for oxide cathodes, which theory is mentioned but not detailed (1). The second survey paper is review of recent work on oxide cathodes, including the mobile donor theory, pore conduction, and the attempts to identify the active centers in oxide cathodes (2). The third paper is not strictly a survey paper but merits special mention because of its examination of the effects of surface fields on the distribution of donors and conduction electrons within a semiconducting cathode (3).

(*c*) *The Cathode Interface Layer.* — Work on the physics of cathode interface layers appears to have dropped off during the past three years. The lack of interest probably stems from lack of a practical incentive now that it is known that low-silicon-bearing base metals eliminate interface problems in commercial tubes. One of few papers on the subject presents life data on tubes having various silicon contents in the cathode base metal. Tubes with 0.2 percent silicon in the base metal develop cathode resistances of 10^3 ohms in 24 000 hours, whereas tubes with 0.05 percent silicon develop resistances of about 200 ohms in the same period (4). A second paper shows that fluctuations in the resistance of interface layers gives rise to noise in the plate current of tubes having substantial interface resistance (5).

(*d*) *Pore Conduction.* — The role of pore conduction in determining the conductivity of oxide cathodes has received further confirmation (6, 7, 8). The work of Forman on conductivity and Hall effect in oxide cathodes is particularly convincing (6). Hall mobilities of the order of 10^5 are found, values which accord with the mean-free-path to be expected in pore conduction.

Pore conduction is also invoked to explain flicker noise in oxide cathodes (9). Fluctuations in coating resistance near the surface of the cathode are assumed to modulate current issuing from pores, thus producing flicker noise [1].

(*e*) *Mobile Donors.* — Past work on the role of mobile donors in oxide cathodes is summarized in one of the survey papers (2), including the work of Frost (10). A more recent paper finds two types of current decay in diodes, a decay with a time constant of the order of 10^{-2} second which is attributed to donor redistribution and a decay with a time constant of the order of 10^{2}-10^{4} seconds which is attributed to a change in the total donor content of the cathode (11). The latter type of decay may well be associated with the sublimation effects to be discussed in the next section of this review.

(*f*) *The Donors in Oxide Cathodes.* — Much effort has been devoted to the identification of the active donors in the oxide cathode. The spectral dependence of the optical enhancement of thermionic emission of (BaSr)O cathodes has been studied (12). A number of peaks in enhancement are observed, but the relation of these peaks to excitation of the active donors is obscure. Professor Sproull and his students at Cornell have done a number of excellent studies of the band structure of BaO (13, 14, 15, 16). The band gap has been established at about 5 ev, and F-centers (oxygen vacancies occupied by electrons) at about 2 ev below the conduction band. The work of Timmer is particularly pertinent to the nature of donors in the oxide cathode (16). A series of studies have led to the general feeling that the « free » barium hitherto assumed to be responsible for the activity of oxide cathodes can not in fact exist, or, if it does exist, it is not directly related to the activity of the cathode (18, 19, 20, 21). Timmer measured the density of color centers (F-centers) in BaO as a function of ambient Ba vapor pressure. He found that to maintain the concentration of color centers required for an active cathode the barium vapor pressure required is of the order of 10^{-6} mm of Hg. Therefore,

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[1] Flicker noise has always been an annoying property of oxide cathodes. It apparently has many possible sources, interface resistance (19), pore conduction (9), ion emission from the cathode (17) and perhaps other sources.

in any tube pumped to 10^{-7} mm of Hg or better F-centers (excess Ba) can not be responsible for cathode activity.

In a series of studies of the labile equilibrium between an oxide cathode and its ambients (chiefly CO_2, CO, O_2, H_2 and H_2O) as a function of temperature, pressure and voltage across the cathode coating, Plumlee found that whereas the rate of evaporation of CO_2, CO, O_2 and H_2 increased with voltage across the coating, the rate of evaporation of H_2O decreased with voltage (22). This behavior and other considerations led him to postulate that the active donor in BaO is in fact $Ba^{++}(OH.e)^{--}$, i.e., a proton and an easily ionized electron attached to a lattice oxygen ion (23, 24). While the nature of the active donor in oxide cathodes requires further study, there is convincing evidence that this donor is not excess barium. This conclusion is not viatiated by the fact that reducing agents enhance the emission of oxide cathodes. The formation of any donor, whatever its nature, is in fact a chemical reduction of the emitting material (24).

(*g*) *Evaporation and « Electron Sputtering »*. — Because the life of a cathode is in part determined by the rate of evaporation of its constituents, considerable work is concerned with measuring rates of evaporation of various constituents of cathodes (25, 26, 18, 22, 27). It is clear that the reducing agents used to enhance the activation of cathodes also enhance the rate of evaporation of the host crystal (27).

« Electron sputtering » has long been a subject of controversy. The liberation of gases by solids subjected to electron bombardment has long been known. However, the mechanism by which known deposits, such as BaO, on metals liberate O_2 under electron bombardment has been obscure. Earlier work suggested that the threshold for liberation had the electron energy equal to the heat of dissociation of the compound bombarded. This behavior was difficult to understand, because the unfavorable mass ratio should make it impossible for an electron to transfer all of its kinetic energy to an atom or molecule. Recent work indicates that the electron energy must be considerably greater than the heat of dissociation (28). A second paper proposes a new mechanism for the dissociation of BaO under electron bombardment (29). The mechanism proposed is the production of hole-electron pairs by the impinging electrons accompanied by a reduction in binding

energy which enhances evaporation. This mechanism at least does no major violence to established notions of conservation of momentum and energy.

(*h*) *L-Cathodes.* — The theory of the L-cathode is thoroughly examined in a pair of papers (30, 31). In the first it is shown that Ba and BaO have migration lengths large compared to the average pore separation so that the surface can be completely covered. The binding energy of BaO on the tungsten surface is found to be about 2.1 ev and the diffusion activation energy about 0.7 ev. The covered surface has Richardson constants of Ao = 2.5 amperes cm^{-2} $degrees^{-2}$ and $\varphi o = 1.67$ ev. The second paper discusses the chemistry of the cathode which determines its activity and life, and the Knudson flow by which Ba is brought to the emitting surface to react with O_2 on the tungsten to form BaO.

(*i*) « *Thin-Film* » *Emission.* — In his last published paper, A. Eisenstein, who contributed so much to the understanding of oxide cathodes, described his work with Russell on the emission of barium oxide films evaporated onto a nickel base (32). He obtained normal BaO emission from such cathodes when the average coverage of the nickel surface exceeded one monolayer and the substrate temperature was held in the range 450°-800° during deposition. Electron diffraction measurements of films prepared in this way showed diffraction patterns corresponding to crystallites with a lattice spacing of 5 $\pm$1 Å. This led to the conclusion that the BaO deposited moved along the surface by surface diffusion to form crystallites and that the crystallites were the source of emission. This work may turn out to be Eisenstein's most important contribution to a field in which he contributed much.

(*j*) *Conclusion.* — This brief report has attempted to high-light recent work on the physics of thermionic emitters under a few headings. Such a summary cannot do justice to all of the work reported in the literature. It is hoped that no grave injustice has been done.

(v) Report on Progress in Gaseous Electronics

(*a*) *Introduction.* — Gaseous electronics, in a general sense, has extensive ramifications. At one extreme, for example, there are determinations of atomic cross-sections for electron impact. At

the other, statistical ensembles of particles interacting with their self-generated fields are dealt with in hydromagnetic theory, and appear in some aspects of galactic physics. Between these limits, one finds Townsend avalanches, glows, arcs, and so on. Such thinking suggests an order of discussion of significant advances in the field — from those involving single particles to those involving more complicated distributions. The period covered extends from mid-1954. One must recognize that, in cases, work representative of an area must suffice for quotation ; and that the stimulus of foreign work cannot be dealt with.

(*b*) *Cross-Section Measurements.* — A brilliant experiment on photo-detachment of electrons from H^- and D^- has been done by Branscomb and Smith (1). Experimental difficulties are considerable, involving the production of an atomic negative ion beam and its weak interaction with crossed approximately monoenergetic radiation. Agreement with theory is excellent.

Baranger and Gerjuoy (2) have made an interesting application of nuclear theory (Breit-Wigner one-level formula) to calculation of helium metastable excitation (3) $S_1(1s, 2s)$; a companion experimental study of the cross-section by Schulz and Fox (3) is also reported.

The use of microwave techniques, involving statistical distributions, has been employed to measure the probability of collision for momentum transfer P_m of slow electrons with atoms. All these experiments involve measurement of the conductivity of the plasma, and deriving P_m as a function of energy. A second « heating » microwave field may be applied to alter the average electron energy. Gould and Brown (4) measure PZ for helium over the electron energy range 0.01-2.5 ev, agreeing with previous measurements at the high energy limit. Gilardini and Brown (5) have recently advanced this art both theoretically and experimentally, and report on PZ for 0.25-1.5 ev electrons in neon. Anderson and Goldstein (6), using the « Luxembourg effect » variation of the technique, have obtained a somewhat higher value of PZ in helium in the range 0.04-0.4 ev, and have also measured PZ in nitrogen. This latter method also gives information on the fractional energy loss on collision, thus also on molecular rotational and/or vibrational excitation.

The theory of Auger ejection of electrons from metals by positive ions has been developed by Hagstrum (7), and well correlated with his definitive experiments. Technique is altogether exceptional, involving the incidence of mono-energetic ions on atomically clean metal targets. The emission γ_1 per incident ion is measured for all rare gases on clean tungsten and molybdenum (8). The effect of partial monolayer adsorption in reducing γ_i is investigated ; indeed, the technique has been used as a tool to detect the formation of metastably excited rare gas ion (10).

Sputtering of cathodes by ions has been studied for a long time. Wehner (11) reports experiments indicating that the process is one of momentum transfer. Detailed results are given of sputtering yield versus angle of incidence on single crystals, type of metal, and so on.

(*c*) *Coefficients.* — This category deals with coefficients pertaining to statistical distributions.

Afterglow studies are useful in this area. Persson and Brown (12) demonstrate by microwave techniques the time decay of density in hydrogen, obtain the ambipolar diffusion coefficient, and do not detect electron-ion recombination. Phelps (13) uses an optical absorption technique to study the lifetimes of helium singlet and triplet metastables. Singlets are lost by diffusion, single collisions, and conversion to triplets by thermal electrons ; triplets are lost by diffusion and triple collisions to form molecules. Diffusion coefficients and conversion cross-sections are reported.

The pulsed Townsend technique has been extended by Burch and Geballe (14) to the study of positive and negative ions in oxygen. O_2^-, O_3^- and O^- are detectable by their mobilities, which increase in that order ; rate of clustering of such ions is discussed.

Ionization coefficients α/p as functions of E/p for some molecular gases have been reinvestigated, clearing up some old mysteries and generating some new ones. Rose (15) reports measurements over an extended range of E/p for hydrogen and deuterium, and brings all recent *dc* hydrogen work into good agreement. α/p at low E/p is considerably higher for D_2 than for H_2, and appears not explainable by mass difference alone. An interesting comparison can be made with the work of Madan, Gordon, Buchs-

baum and Brown (16), who measure in a microwave breadkown experiment, the high frequency ionization coefficient for hydrogen. In theory, the two coefficients should be related through the average electron energy ; the more carefully the *ac* and *dc* experiments are performed, the more it appears that this cannot be so. DeBitetto and Fisher (17) make a study of conditions at higher pressure over a limited range of E/p, in both H_2 and N_2, obtaining α/p and γ_i. Harrison (18) reports further results on α/p in N_2.

(*d*) *Breakdown and Glows.* — The role of field emission on high field breakdown is shown by Boyle and Kisliuk (19). The effect shows up as a departure from Paschen's law at high pressure and small electrode separation ; the operative nonlinear effect is the effect of field enhancement near the cathode by ions. Boyle, Kisliuk, and Germer report the same situation in high vacuum breakdown for short gaps (20) ; ions are produced by electron impact on the anode.

Two papers by Warren (21) deal with electric field distribution in the cathode region of *dc* abnormal glow discharges in N_2, H_2, He and A. The field, as probed by a transverse electron beam, does not rise quite linearly toward the cathode from the negative glow, as is often assumed. The particular dependence is explained in terms of electrons ionizing in the glow, and ions returning by quasi-equilibrium drift in the field, and sometimes ionizing the gas by collision on the way.

Fluorescent lamp plasmas have been analyzed by Waymouth and Bitter (22). Such lamps contain an inert gas whose sole purpose is to inhibit diffusion losses from the mercury vapor plasma. Ionization by electron impact with excited atoms, and loss of particles and radiation make for a complex balancing theory ; qualitative agreement is obtained with experiment.

The interaction of microwave fields and plasmas receives considerable study. Rose and Brown (23) extend Boltzmann theory to include the non-linear self-electrostatic field and calculate the maintaining electric field of a hydrogen plasma. Agreement with experiment is obtained over a range of pressure and charge density. Schulz and Brown (24) compare measurement of electron density by *dc* probe and microwave techniques. For agreement, probe theory must be modified to take into account the directed ion current to the sheath edge. A theoretical paper by Wolff (25)

describes the phenomenon of plasma resonance in terms of normal modes characteristic of the plasma, and including the effect of density gradients. Microwave techniques for measuring high electron densities have been analyzed theoretically by Persson (26), and more as a technique by Buchsbaum and Brown (27). The electric polarization limit caused by *ac* space charge is circumvented by proper choice of field configuration.

Much work has been done on the retrograde motion of the mercury arc spot in a magnetic field. Hernqvist and Johnson (28) have discovered that the so-called « ball-of-fire » hot cathode glow has the same behavior. They have studied the effect and propose a theory based on stability criteria of the space charge sheath. A further application by Hernqvist (29) to the mercury pool arc is shown to agree with experiment.

(*e*) *Highly Ionized Plasmas.* — This area is now the most active part of gaseous electronics. Unfortunately, much work is classified, but some significant papers can be mentioned.

Ionization by shock waves probably belongs here. Lin, Resler and Kantrowitz (30), and later Lamb and Lin (31) study the degree of ionization and conductivity in strong shocks in argon and air. For this latter gas, it is remarkable that the measured electrical conductivity agrees with that calculated on the basis of thermal ionization, because many interaction cross-sections enter the theory in a rather critical way.

Allied to the problem of magnetic confinement of a plasma are two studies by Simon on particle diffusion in a magnetic field. In one paper (32), animalously large diffusion previously surmised to arise from oscillations is shown to be due to slight differential flow along field lines. In the other (33), like-particle diffusion across the field is shown not to obey Fick's law, but to depend on high space derivatives of density. Similar results are derived by Tonks (34), and Longmire and Rosenbluth (35).

Application of Boltzmann theory to highly ionized gases has been made by Watson (36), and Bruekner and Watson (37). An individual particle orbit approach is used in static solutions. Non-static cases are treated as linearized perturbations, and particular examples of hydromagnetic waves and gravitational instability are given.

A novel form of highly ionized plasma (the « plasmoid ») is reported by Bostick and associates (38). These small entities are fired from a button source and maintain their identity while crossing a magnetic field. They are presumably polarized thereby, and several of them can be projected at each other and made to interact.

The fascinating search for thermonuclear power has yielded few publications to date. Burkhardt et al. (39) report studies of the pinch effect in toroidal and straight tubes. The whole field is summarized in Post's classic article (40). The problem is set forth in terms of the orders of magnitude that must be considered — of Earth's available fuel supply, thermonuclear cross-sections, mean free paths, power density, temperature, and so on. Here is gaseous electronics of heroic proportion indeed.

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Report of the Chairman of the Commission

to the Plenary Opening Session

During the three years that have passed since the Assembly at the Hague, extensive correspondence among the Members of Commission VII has done much to decide the subjects to be discussed by and the most useful form of the meetings of the Commission on Radio-Electronics. Eighteen months ago we had decided on the four topics which we would cover here in Boulder; this early start was made in order that National Chairmen of the Commission could begin to collect information on work on these topics which was proceeding in their own countries. The members further decided that only one formal paper would be given at each of our sessions; all the rest of the session would be given over to reports and discussion by National Chairmen and to discussion by invited authorities on the subject.

Because of a recent and very important development in Electronics this plan has been modified slightly. A fifth meeting has been added and this meeting will take the form of a group of invited papers. I shall mention again later the topic of this meeting, the Maser.

It is fortunate for Commission VII that this Assembly of U.R.S.I. is located in the United States of America. The extensive research in the field of Electronics which is in progress here has made it possible for us to find many distinguished people who were willing and able to help us with our meetings. Through the kindness of the Officers of the American National Committee of U.R.S.I., and with the never-failing help of our Honorary President Dr. Dellinger, it has been possible for us to invite outstanding Americans to chair some of our meetings and to make contributions to our sessions, even though in many cases these gentlemen are not official delegates to U.R.S.I.

The titles of the five Meetings that have been scheduled follow :

Topic	Discussion Leader	Chairman	Date
Oscillation Phenomena In Gas Discharges	Prof. P. W. ALLIS, Massachusetts Inst. of Technology Cambridge, Mass.	Prof. J. L. H. JONKER, Technical Univ., Eindhoven, Aalsterweg 391, Eindhoven, Netherlands.	Thursday Aug. 29 9 h. 30
The Physics of the Cathode	Dr. L. S. NERGAARD, Radio Corporation of America, R.C.A. Laboratories, Princeton, N. J.	Prof. W. G. SHEPHERD, Dept. of Electrical Engineering, Inst. of Technology, Univ. of Minnesota, Minneapolis 14, Minn.	Friday Aug. 30 9 h. 30
The Source and Nature of Noise in Electron Beams	Dr. J. R. PIERCE, Murray Hill Labs., Bell Telephone Labs., Inc. Murray Hill, New Jersey, U. S. A.	Prof. A. BLANC-LAPIERRE, Faculté des Sciences, Université d'Alger, Alger	Monday Sept. 2 9 h. 30
The Physics of Semi-Conducting Devices for Radio Application	Dr. Wm. SHOCKLEY, Shockley Semi Conductor Laboratory, Beckman Instruments, Inc., 391 S. San Antonio Rd. Mountain View, Calif.	Dr. M. TANNENBAUM, Murray Hill Labs. Bell Telephone, Murray Hill, New Jersey, U.S.A.	Tuesday Sept. 3 9 h. 30
The Maser (Joint with Comm. V)	Prof. C. H. TOWNES Columbia University, New York, New York	Dr. R. C. FLETCHER, Murray Hill Labs. Bell Telephone Labs Inc., Murray Hill, New Jersey, U.S.A.	Tuesday Sept. 3 14 h. 00

Our decision to devote two Meetings to Solid-State Physics reflects the fact that in this subject great advances are being made which are of importance to all who are interested in radio measu-

rements. Because the Session on the Maser was organized somewhat later than the others, and so could not be given the same publicity, I would like to stress its importance. The Maser is a quantum mechanical amplifier of micro-wave energy ; if it fulfills its promise it will exhibit such an extremely lownoise figure that many radio measurements may be expected to be greatly affected by its introduction. The Meeting on the Maser is to be joint with Commission V on Radio Astronomy. I must thank the Chairmen of the other six Commissions of U.R.S.I. who have arranged that their Commissions will not meet at the time of the Maser Meeting, so that all who wish may attend.

The members of Commission VII believe that a number of the topics that we are to discuss will be found of interest to all members of U.R.S.I. whether or not their primary interest is in Radio-Electronics. We invite you to investigate our programme and should you find it interesting, to join us in our meetings and take part in the discussions.

In conclusion I would like to acknowledge the great effort made by the Chairmen of the five meetings in organizing these sessions. I would particularly like to thank Dr. Shepherd, the Chairman of Commission VII in the United States, for his many ideas and contributions.

Minutes of the Sessions

ADMINISTRATIVE SESSION, AUG. 26th, MONDAY

The business meeting of Commission VII was held Monday, August 26 at 1400. The countries represented and official members included : Canada (BURGESS), Italy (TIBERIO), Germany (ROTHE), Japan (ASAMI), Netherlands (JONKER), Sweden (ROHDIN), Switzerland (TANK), United Kingdon (OATLEY), U.R.S.S. (STELMACH) and U. S. (SHEPHERD).

During the early part of the meeting concerned with the arrangements for the technical session other delegates of Commission VII also participated.

Five sessions were organized. The subjects and other relevant data for these sessions are listed.

Topic	Discussion Leader	Chairman	Date
Oscillation Phenomena In Gas Discharges	Prof. P. W. ALLIS, Massachusetts Inst. of Technology, Cambridge, Mass.	Prof. J. L. H. JONKER Technical, Univ. Eindhoven, Aalsterweg 391, Eindhoven, Netherlands.	Thursday Aug. 29 9 h. 30
The Physics of the Cathode	Dr. L. S. NERGAARD, Radio Corporation of America, R.C.A. Laboratories, Princeton, N. J.	Prof. W. G. SHEPHERD, Dept. of Electrical Engineering, Inst. of Technology, Univ. of Minnesota, Minneapolis 14, Minn.	Friday Aug. 30 9 h. 30

Topic	Discussion Leader	Chairman	Date
The Source and Nature of Noise in Electron Beams	Dr. J. R. PIERCE, Murray Hill Labs. Bell Telephone Labs., Inc. Murray Hill New Jersey, U. S. A.	Prof. A. BLANC LAPIERRE, Faculté des Sciences, Université d'Alger, Alger.	Monday Sept. 2 9 h. 30
The Physics of Semi-Conducting Devices For Radio Application	Dr. Wm. SHOCKLEY, Shockley Semi-Conductor Laboratory, Beckman Instruments, Inc., 391 S. San Antonio Rd., Mountain View, Calif.	Dr. M. TANNENBAUM, Murray Hill Labs. Bell Telephone, Murray Hill, New Jersey, U.S.A.	Tuesday Sept. 3 9 h. 30
The Maser (Joint with Comm. V)	Prof. C. H. TOWNES, Columbia University, New York, New York.	Dr. R. C. FLETCHER, Murray Hill Labs. Bell Telephone Labs Inc., Murray Hill, New Jersey, U.S.A.	Tuesday Sept. 3 14 h. 00

In the business portion of the meeting the present chairman of the committee, Professor Woonton, discussed his recommendations to the Executive Committee of U.R.S.I. of possible candidates to be considered for election as the next chairman of Commission VII. Professor Woonton felt that the next chairman should be someone who had participated very actively in the recent work of the Commission and was familiar with its activities. As such, he felt that Dr. BLANC-LAPIERRE of France, Dr. JONKER of Netherlands or Dr. SHEPHERD of U. S. would be suitable candidates. His recommendations were approved by the Commission. However, Dr. JONKER asked that his name be withdrawn as he felt he could not do justice to the post because of his heavy committments in organizing an electrical engineering department in the new Institute of Technology being built in Eindhoven.

Dr. JONKER was nominated by W. G. SHEPHERD for re-election as vice-chairman of the Commission, seconded by C. OATLEY

and election was unanimous. The election of a secretary was postponed until after the selection of the new chairman since it was felt that if possible the secretary should be someone located geographically close to the chairman. M. CHODOROW, U. S. was appointed Secretary pro-tem for this assembly.

The official reporters of the Commission for the various sessions were :

English Language

Oscillation Phenomena : EMELEUS.
Physics of Cathodes : OATLEY.
Noise in Beams : CHODOROW.
Semiconducting Devices : OATLEY.
Maser : BURGESS.

French Language

BLANC-LAPIERRE (All Sessions).

SESSION ON « OSCILLATION PHENOMENA IN GAS DYNAMICS »

(*Chairman* : Prof. P. W. ALLIS)
August 30 at 9 h 30 and 14 h

Papers were read and discussed on the above topic, interpreted broadly.

The introductory paper was given by W. P. ALLIS (U. S. A.) on « Oscillation Phenomena in Gas Discharges ». This reviewed critically the still controversial subject of the statistical mechanics of plasmas, with or without beam of charged particles passing through them. Two points of special interest were (*a*) the speaker pointed out that the so-called Langmuir frequency was known to Rayleigh as early as 1906 ; (*b*) the sharp onset of oscillations a few mm in front of a hot cathode at low pressure is explicable in principle by a modified application of klystron theory.

K. G. EMELEUS (U. K.) gave a short survey of the work done by Gabor in London, and in his own laboratory, in Belfast. Gabor's work is on sheath oscillation, the remainder of *uhf* plasma-

electron and electron beam oscillations, lower frequency (« ionic ») oscillation of various types, particularly moving stratums, and on low-frequency (less than 100 Mc/s) noise from low-pressure discharges.

I. B. BERNSTEIN (U. S. A.) gave a paper on « Stationary Waves in a Plasma ». In this the problem of a one-dimensional non-linear electrostatic wave in a plasma free from interparticle collision was solved exactly by elementary means. Essentially arbitrary travelling wave solution can be constructed by adding appropriate number of particles trapped in potential energy troughs. The analysis, although incomplete in relation to certain factors which occur in practice, raises the question of the importance of Landau damping.

W. A. NEWCOMB (U. S. A.) gave a paper on plasma oscillations in a magnetic field. The theory for zero magnetic field has been generalized for the case of a finite field, both without and with allowance for thermal motion of the electrons. The analysis becomes somewhat complicated because the electron stress tensor is not isotropic. This paper appeared of particular interest from the way in which the transition from light waves to plasma oscillations was traced.

Y. ASAMI (Japan) in an account of work done by himself and others in his country drew attention *inter alia* to an early paper by himself and M. SAITO entitled « Resonance Phenomena in Ionized Gases and Their Effect on the Propagation Characteristics of Electromagnetic Waves ». This was published in 1939 (Nippon Electrical Communication Engineering No. 15). Further work in progress or done recently was also referred to covering researches on moving striations, the ball of fire discharge in a magnetic field, and fluctuations in discharges.

A. BLANC-LAPIERRE (France) read a paper on « Interference Phenomena in Gas Discharges ». In this he gave an account of experiments done by M. CLOUPEAU (Paris), consequent on earlier similar ones by Professor LAPORTE, a rotating mirror was used to study the aperiodic discharge of a condenser through a tube containing xenon. Under suitable conditions, mechanical oscillations were observed which are attributable to reflection at the tube wall of the shock wave produced by expansion of the discharge channel. This was the only paper in which attention was concen-

trated on the electro-acoustic effects which may occur in a considerable range of discharges.

L. G. H. Huxley (Australia) described some new Townsend type experiments on the « Motion of Free Electrons in Nitrogen », analyzed rigorously which gave information about collision frequencies in the near-thermal energy range which is of particular importance for the ionosphere.

R. W. Gould (U .S. A.) gave paper by himself, L. N. Field and G. Boyd. An electron stream sent through a high density plasma should show strong amplification for applied frequencies below and slightly above the plasma frequency, which may account for some solar noise. A laboratory model was described which illustrates this and operates successfully. Experiments have been carried out from 2000-4000 Mc/s, with gains of 20-40 db/cm and reflection at several frequencies.

J. Feinstein (U. S. A.) in a paper on the « Propagation of Plasma Oscillations » discussed the absence of these, except near the exciting beam in laboratory experiments. This result was attributed tentatively to a layer effect of collisional damping when the dispersion nature of the plasma electron waves is allowed for introduction of the group velocity.

L. D. Smullin (U. S. A.) discussed further « propagation in ion filled wave guides » with a superimposed axial, d.c., magnetic field, particularly the equation for TM_{01} waves. The problem is in general very complicated, but analytic results are simply obtained with certain simplifying assumptions, which indicate the existence of pass bands.

E. Gordon (U. S. A.) gave a paper on « Generation of Plasma Oscillations ». In this he discussed the origin of Gabor's sheath type and described an extensive series of new experiments on the generation of oscillations by beams. The latter extend considerably the work of Merrill and Webb, and of Allen and Emeleus, and were, further, subjected to theoretical analysis. A major point which emerged was the apparent necessity for feed-back, roughly speaking as in a reflex klystron, if oscillations of difficult frequencies are to be maintained ; otherwise, there is considerable experimental evidence that much mode-jumping takes place.

SESSION ON « THE PHYSICS OF THE CATHODE »

(*Chairman* : Prof. W. G. SHEPHERD)

August 30, 9 h 30

The meeting was opened by L. S. NERGAARD, who said that he had been asked to deal with problems on the present frontiers of research on the cathode. To do this, he would state and discuss four propositions, which could not necessarily all be proved, as follows :

(*a*) Every cathode is a reducing agent,

(*b*) Every cathode lives in equilibrium with its environment,

(*c*) Every cathode is a dispenser cathode, and

(*d*) Monolayer-film cathodes do not exist.

Evidence in support of these propositions was adduced from a wide range of experimental results and many old results were interpreted in a new light.

The validity of some of the propositions was questioned in a paper by E. S. RITTNER (presented by A. VAN DER ZIEL) which gave details of experimental results with L-cathodes.

W. E. DANFORTH next contributed some data on thorium dispenser cathodes, which he thought were consistent with the monolayer theory.

Experiments by W. G. SHEPHERD, D. E. ANDERSON and D. R. PALMER in which the roles of chemical and electrolytic actions in the activation of oxide cathodes had been separated, were described by W. G. SHEPHERD. The activity of the cathode had been determined by measuring its pulse emission and the influence of reducing agents in the base metal had been clearly demonstrated. The deactivation of the cathode when current was drawn from it had also been studied.

The sizes of crystallites in the oxide coating have an effect on the activity which can be obtained from a cathode. This effect had been studied by K. M. YAZAWA and H. YAKO, using an electron microscope, and their results were described by M. HATOYAMA, who also gave details of work by H. KAWAMURA on other factors affecting the activity of cathodes. In particular, KAWAMURA had studied the effect of ambient oxygen pressure.

A paper by P. A. Redhead and C. R. Crowell on cathode properties under space charge limited conditions was presented by R. E. Burgess. This dealt with the problem of determining the saturation current from measurements made of the point of inflexion of the saturation curve. Perturbation of space charge in the vicinity of the cathode was also discussed.

V. L. Stout described experiments by J. E. Beggs and himself on the use of titanium as a material for the construction of anodes. This metal has the ability to dissolve its own oxide and thus maintain a clean surface ; in consequence, the behaviour of the cathode is affected. The experiments thus show the importance of interaction between anode and cathode.

Finally, A. van der Ziel showed how the study of flicker noise could be used to obtain information about the mechanism of conduction in the oxide coating. Theory indicated that grain conduction would be noisier than pore conduction and the two mechanisms could thus be distinguished.

Session on the « Source and Nature of Noise in Electron Beams »

(*Chairman* : Prof. A. Blanc-Lapierre)

September 2, at 9 h 30

The discussion leader, J. R. Pierce, U. S. A., gave the opening paper on the source and nature of noise in electron beams. He discussed the recent progress in the understanding and the measurement of shot noise in electron beams and its implications for the noise figure of amplifiers. In the past three years, knowledge of this problem has increased greatly and although there are still some gaps in our understanding, these are much smaller than previously. With this increased understanding has also come greatly improved performance of low noise amplifiers. The other contributed papers discussed in somewhat greater detail the experimental and theoretical aspects of this subject. The detailed program is given below. The nature of the subject is evident from the titles.

1. J. R. Pierce (U. S. A.). — The Source and Nature of Noise in Electron Beams.

2. Jiro-Koyama (presented by Hatoyama) (Japan). — Microwave Noise at the Potential Minimum.
3. Seiyo Okochi (presented by Hatoyama) (Japan). — On the Microwave Noise at the First Anode in Electron Beam.
4. E. V. Kornelsen, R. F. C. Vesso, G. A. Woonton (Canada). — Current and Velocity Fluctuations at the Anode of an Electron Gun.
5. P. Grivet (France). — Experimental Results on Noise in Beams.
6. W. W. Rigod (U. S. A.). — Noise Growth in Drifting Electron Streams.
7. L. J. Chu, H. A. Haus (U. S. A.). — The Kinetic Power Theorem for Longitudinal Electron Beams.
8. H. A. Haus (U. S. A.). — On the Minimum Noise Figure of Microwave Beam Amplifiers.
9. Saito (Japan), Smullin (U. S. A.). — The Measurements of Correlation between Currents and Velocity at the Potential Minimum.
10. J. R. Whinnery (U. S. A.). — Some Three Dimensional Noise Effect Important for Backward Wave Amplifiers.
11. W. E. Danielson (U. S. A.). — Emergence of the Travelling Wave Tube as a Practical Low Noise Device.
12. J. R. Pierce (U. S. A.). — Summation.

Session on « The Physics of Semiconductors for Radio Applications »

(*Chairman* : Dr. Tannenbaum)

September 3, 9 h 30

The meeting was opened by Dr. Shockley who presented a paper in which he discussed some of the problems which arise when an attempt is made to scale down the size of a transistor, so that it can operate at higher frequencies. He first derived the scaling laws which, from elementary considerations, would be expected to apply. These suggest that the maximum frequency of operation should be inversely proportional to the square of the linear dimensions of the transistor. However, this assumes a constant mobility, whereas in fact the mobility of carriers is a function of the electric field at high field strengths. Again the scaling laws must be modified when the size of the transistor becomes so small that the thickness of the base layer is comparable with the mean free path of a carrier.

Because of these complications, it has not yet proved possible to set an upper limit to the frequencies at which transistors may ultimately operate.

A. VAN DER ZIEL next presented an account of some theoretical work on noise in diodes and transistors and explained that his formulae (which ignored flicker noise) were independent of the mechanism by which recombination takes place. They might, however, be upset by space charge or by high trap densities.

Results of measurements of electronic noise in bulk semiconductors were given by K. M. VAN VLIET, showing good agreement with theory. Good modern crystals have very little noise varying inversely with frequency.

R. E. BURGESS discussed some theoretical aspects of noise calculations, distinguishing between time-dependent and space-dependent fluctuations.

An account of measurements on flicker noise, carried out by N. NIFONTOFF was presented by A. BLANC-LAPIERRE. Systems investigated included point-contact, barrier-layer and junction rectifiers, and barrier-layer and junction photocells.

A new method of investigating potential variations in *p-n* junctions, using a scanning electron microscope, was described by C. W. OATLEY.

A paper by W. SASAKI, on some measurements of the acousto-electric effect, was presented by G. M. HATOYAMA. The results obtained showed that the effect was independent of frequency over the range from 20-80 kc/s.

H. SALOW described a new type of switching transistor which was easy to manufacture, had high sensitivity and could be operated at high speeds. Rise-times of the order of 0.02 μs could be achieved.

The meeting ended with a paper by A. D. MACPHERSON on point-contact microwave crystal mixers. In this the problem of predicting microwave performance from low-frequency measurements was discussed.

SESSION ON THE MASER

(*Chairman* : Dr. R. C. FLETCHER)

September 3, 14 h

1. The Chairman Dr. R. C. FLETCHER (Bell Telephone Laboratories) opened the session by outlining briefly the history, principle and application of the Maser and introduced the keynote speaker.

2. Prof. C. H. Townes (Columbia University) spoke on « Properties of Masers — Theory and Present Experience. »

He made a general plea for the use of atomic and molecular resonance (especially at wavelengths shorter than a few millimeters) to provide filters, amplifiers and oscillators. The general principle of upsetting thermal equilibrium between various energy levels and triggering transitions by microwave radiation gave the possibility of amplification. In a cavity the wave may be made to traverse the substance used many times and feedback can also be introduced. To override losses in the cavity the dipole moment p must be large as well as the spin-spin relaxation time T_2 which determines the « molecular bandwidth ». Either ammonia gas or paramagnetic solids are commonly used giving molecular bandwidths of a few kc/s or a few Mc/s respectively. Although the ammonia Maser is restricted in power output to about 10^{-9} watt it is capable of providing a monochromatic output with a frequency constancy of 1 in 10^{12}. In an amplifier, the noise is of a very low level and arises from the discrete nature of photons and from spontaneous emission. Several practical embodiments of the Maser principle were described with discussion of multilevel schemes, excitation methods and of the factors determining bandwidths.

Gordon, Zeiger, Townes. — *Phys. Rev.*, **99**, 1264-1274 (1955).
Shimoda, Wang, Townes. — *Phys. Rev.*, **102**, 1308-1321 (1956).
Shimoda, Takahasi, Townes. — *J. Phys. Soc. Jap.*, **12**, 686-700 (1957).
Combrisson, Honig, Townes. — *C. R.*, **242**, 2451-2453 (1956).

3. Dr. H. E. D. Scovil (Bell Telephone Laboratories) spoke on « The Three Level Solid State Maser. ».

He emphasized the importance of the ratio of the spin-lattice to the spin-spin relaxation time (T_2) which is usually of the order of 10^4 and showed how the 3-level scheme could be arranged to give a negative temperature between the closest pair of states.

Practical problems involved are : boiling of the helium by the pumping power (typically about 40 mW), the need to obtain a good filling factor and the noisiness which arises largely from insertion loss. A typical amplifier pumping at 11 kMc/s and operating at 6 kMc/s gave a gain of 20 db with a bandwidth of 100 kc/s and an effective noise temperature of 150° K.

BLOEMBERGEN. — *Phys. Rev.*, **104**, 324 (1956).
FEHER, SCOVIL. — *Phys. Rev.*, **105**, 760-2 (1957).
SCOVIL, FEHER, SEIDEL. — *Phys. Rev.*, **105**, 762-3 (1957).

4. A. M. PROKHOROV (Lebedev Institute) offered some « Remarks on the Three-Level Maser ». In calculating the transitions between levels one can use the psi-function approach. An equivalent circuit for the system consists of an LCR circuit with a complex capacitance. With strong pumping the Maser can operate as an amplifier at two frequencies simultaneously and oscillation can be obtained at more than one frequency. However such a system is not suitable for oscillators of high frequency stability.

BASOV, PROKHOROV. — *Dokl. Akad. Nauk.*, **101**, 47 (1945).
BASOV, PROKHOROV. — *Zh. Eksp. Teor. Fiz.*, **28**, 249-250 (1955).

5. H. TAKAHASI (University of Tokyo) spoke on « High Frequency Amplification with Non-Linear Reactance Elements. »

There are numerous examples of parametric amplifiers an important example being the dielectric amplifier using barium titanate. Some general theorems can be established regarding power relations in a lossless non-linear reactance, e.g., if frequencies f_1 and f_2 are applied to give an output at $f_0 = f_1 + f_2$ then $P_1/f_1 = P_2/f_2 = P_0/f_0$. This is a classical analog of the quantum addition law, and it can be extended to the case of an output at the difference frequency. These systems are analogous to the 3-level Maser in which P_0 corresponds to the power supply at the pumping frequency. Such systems in linear operation can be represented by an impedance matrix (not symmetric) from which the condition for oscillation may be readily derived. A ferromagnetic reactance amplifier using ferrite cores with a number of suitably coupled windings was described in some detail.

MANLEY, ROWE. — *Proc. I.R.E.*, **44**, 904-913 (1956).

6. H. SUHL (Bell Telephone Laboratories) discussed « Microwave Amplification using Ferromagnetic Materials. »

Interesting possibilities arise from Bloembergen's observation of anomalies in ferromagnetic microwave absorption at high power levels. Theoretically, one may use Kittel's treatment to determine the modes for the magnetization vector M with a specified dependence of M on position and time. At low frequencies where the

dimensions are small compared with the wavelength the « magnetostatic » modes are found (c. f. L. H. WALKER's results). Only at infinitesimal fields is the problem linear and at finite fields it becomes non-linear and the modes become coupled ; the magnetostatic modes tend to give a continuum while the electromagnetic modes are discrete. An equivalent circuit can be derived for such a system when two frequencies f_1 and f_2 are present whose sum equals the precession frequency fp of M ; this consists of two series resonant circuits (at f_1 and f_2) having a common impedance modulated at f_p. Striking effects can occur under these conditions and amplification becomes possible ; in one system a voltage gain of 30 with a 1 Mc/s bandwidth has been obtained.

SUHL. — *Proc. I.R.E.*, **44**, 1270-84 (1956) ; *Phys. Rev.*, **101**, 1437-8 (1956) ; *Phys. Rev.*, **106**, 384 (1957).

7. J. G. BOLTON (Mount Wilson and Palomar Observatories) considered « The Future Importance of Low Noise Amplification to Radio Astronomy and Radio Wave Propagation. »

At frequencies above 500 Mc/s the background noise in the antenna from the galactic continuum (and the ground and atmosphere) is of the order of 10° K and a receiver with a low effective noise temperature is therefore needed. The limitations of cost and mechanical structure imposed on the maximum size of antenna emphasize this need for very low noise amplifiers. The subjects of study at these frequencies are : galactic continuum, other galaxies (especially M 31), the 1420 Mc/s hydrogen line and absorption in the hydrogen envelope of radio stars. The work on the hydrogen line is considered to be very important as it provides the only method of observing the raw material of the universe ; line resolution of about 5 kc/s is required. In the galaxy observations temperatures of about 30° K on M 31 and 5° K on the next nearest galaxy will be involved. The availability of Masers of suitable frequency, gain and bandwidth will greatly assist this program.

8. P. GRIVET presented the ideas of ABRAGAM, SOLOMON and COMBRISSON (Saclay) on « A liquid state Maser for measuring weak magnetic fields. »

Weak magnetic fields can be measured with high accuracy by observing proton magnetic resonance in water which in the

earth's field gives a frequency of about 2 kc/s ; the natural line width corresponds to about 10^{-5} gauss, and the relaxation time T_1 is about 3 seconds. A Maser-like system may be used to observe the weak signal of the proton precession. The potassium sulfonate ion in water gives three levels, and considerable accentuation of the resonance signal may be obtained by virtue of the Overhauser effect.

9. G. M. HATOYAMA presented the work of K. SHIMODA (University of Tokyo) on « The Characteristics of the Beam-Type Maser ». In the ammonia beam type Maser the $N^{14}H_3$ 3-3 line at 23, 870 Mc/s is usually used. Because of quadrupole splitting the output frequency and power vary with the focusser voltage. These undesirable effects can be avoided by using the 3-2 line for which the quadrupole coupling energy disappears and gives a frequency of 22, 834 Mc/s. Alternatively the N^{15} isotope offers the possibility of reducing quadrupole effects.

BUSINESS MEETING, ON SEPTEMBER 4.

Minutes of meeting held on Monday, August 26th, were read by the secretary, M. CHODOROW, and it was moved by SHEPHERD (U. S.) and seconded by OATLEY (U. K.) that the minutes be accepted as read. It was moved by OATLEY (U. K.) and seconded by JONKER (Netherlands) that the new chairman of Commission VII should be authorized to appoint his own secretaries, unamimously carried. It was moved by SHEPHERD (U. S.) that an additional vice-presidency be added to the Commission. This is to be occupied by the immediate past president and would provide continuity to the functioning of the Commission. This was seconded by OATLEY (U. K.) and passed unamimously. Countries represented at this meeting included all those present at the meeting of August 26 except Italy and with the addition of France, represented by BLANC-LAPIERRE.

The nature of future meetings of the Commission was discussed. Based on the successful functioning of the Commission at this U.R.S.I. Conference it was agreed that the following procedure should be followed : (1) the same form of meetings should be held, i.e., a discussion leader to give a long introductory paper with contributed papers in the same field by others. (2) Advance

copies of the leading papers plus abstracts of the contributed papers should be distributed to the people attending the session. (3) In soliciting papers for the meeting, form letters should be sent to the national chairmen, of Commission VII, of the various countries for distribution to interested scientists and also to the official delegate of the Commission at the current U.R.S.I. meeting if he were someone other than the national chairman.

Lists of possible topics for the next meeting and for possible symposia before the next U.R.S.I. conference, included the following :

Fluctuation Phenomena,
Plasma Phenomena,
Molecular Amplifiers,
Microwave Properties of Ferrites,
Electron Dynamics,
Semiconductors,
Electron Emission (Primary, Secondary),
Paramagnetic Resonance,
Luminescence,
Electron Radiation.

In a discussion of the nature of the report of Commission VII to be published in the official U.R.S.I. report, it was moved by SHEPHERD (U. S.) and seconded by JONKER that we ask the Executive Committee of U.R.S.I. to include the bibliographies in the national reports or omit the reports entirely since it was felt that without the bibliography the national reports were not of very great value.

Summary of the Proceedings of the Commission

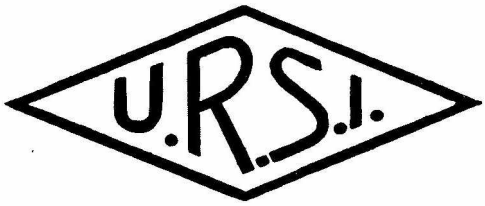
Commission VII on Radio-Electronics has held eight half-day scientific meetings during the period of the XII General Assembly. Delegates and observers of eleven different nationalities participated and co-operated to make these meetings a highly useful medium for the exchange of scientific information on an international scale. The average attendance at the first seven meetings was of the order of fifty people. During its more general portion the eighth meeting, on the Maser, which was held jointly with Commission V on Radio-Astronomy, was attended by about two hundred and seventy five.

The device of binding the meeting together through the agency of a lead paper given by an invited discussion leader has proved effective. In most cases the various contributions that followed the lead paper were closely related to the main topic and gave a sense of unity to the meeting as a whole. In all cases the lead paper and the other contributions involved discussion from authorities who were present which was very valuable indeed. At the final business meeting the use of discussion leaders was endorsed and it has been recommended that they be used by Commission VII during its meetings at the next General Assembly.

Judged from the point of view of general interest, the meeting on the Maser was very successful. The members present from the Commission on Radio Astronomy expressed keen interest in the development of these new devices and urged that Masers be made available for application as soon as possible. It is of interest that at this meeting Dr. SCOVEL of the Bell Telephone Laboratories reported for the first time on the measured noise parameters of their three-level Maser. He said that the measured noise temperature was 150° K of which all but 13° K could be accounted for on the basis of the insertion loss of the external circuitry.

At the final meeting of the Commission a list of topics on which work might be concentrated during the next three years was set-up. From this list it is expected will be chosen the topics which will be discussed at the next General Assembly. The list comprises of topics related to fundamental electronic phenomena in solids, gases and vacuum ; it includes such topics as Fluctuation phenomena, Plasma and the Use of Molecular and Atomic Resonances in Radio Processes.

INTERNATIONAL SCIENTIFIC RADIO UNION



Proceedings of the XIIth General Assembly

held in Boulder, Colorado, U. S. A.
from August 22nd to September 5th, 1957

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U.R.S.I. Executive Committee at the XIIth General Assembly

Introduction

Aknowledgment

At the beginning of this eight and last part which closes the Proceedings of the XIIth General Assembly of U.R.S.I., we wish to convey our thanks :

— to *Unesco* whose financial and moral help facilitated the attendance at this meeting of several scientists interested in the various fields of our activities, and enabled the publication of the Proceedings ;

— to the *International Council of Scientific Unions* whose initiatives led to a more extensive development of our activities ;

— to the *U. S. A. Governmental Agencies* and particularly to the *National Bureau of Standards* which provided a most efficient help for the preparation and the organization of the General Assembly ;

— to the *U. S. A. National Committee* and to the *General Arrangements Committee* whose efforts ensured the big success of this meeting ;

— to the numerous *U. S. A. Commercial Firms* which provided the U. S. A. National Committee with material possibilities.

Honorary Presidents of U.R.S.I.

H. M. Albert, King of Belgium (1914-1934).

Dr. W. E. Eccles, United Kingdom (1934).

Dr. A. E. Kennelly, United States of America (1934-1939).

Prof. R. Mesny, France (1946-1950).

Dr. E. H. Rayner, United Kingdom (1946).

Mr. R. Bureau, France (1948).

Sir Edward V. Appleton, United Kingdom (1952).
Dr. J. H. Dellinger, United States of America (1952).
Prof. Dr. B. van der Pol (1952).

Board of Officers

President : Dr. L. V. Berkner (U. S. A.).

Past President : Father P. Lejay (France) †.

Vice-Presidents : Prof. I. Koga (Japan),
Dr. R. L. Smith-Rose (U. K.),
Prof. G. A. Woonton (Canada).

Treasurer : Prof. Ch. Manneback (Belgium).

Secretary General : Ing. E. Herbays (Belgium).

General Arrangements Committee

Chairman : Dr. J. H. Dellinger.

Finance : Dr. L. V. Berkner.

Local Arrangements : K. A. Norton, A. H. Shapley.

Foreign Arrangements : Prof. W. E. Gordon, H. W. Wells.

Technical Programme : F. H. Dukson, Prof. A. H. Waynick.

Ladies Programme : Mrs Kenneth A. Woonton.

Honorary : Dr. W. W. Atwood Jr., Dr. F. W. Brown, Mr. Quigg Newton.

Attendance of National Committees

National Committees of the following countries were represented at the General Assembly : Australia, Austria, Belgium, Canada, Czechoslovakia, Denmark, Finland, France, Germany (Federal

Republic), India, Italy, Japan, Morocco, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, United Kingdom U. S. A. and U. S. S. R.

Membership of the Executive Committee at the General Assembly

President : R. P. LEJAY *Secretary* : E. HERBAYS

Country	*Member*
Australia	Dr. D. F. MARTYN,
Austria	Mr. O. BURKARD,
Belgium	Prof. Ch. MANNEBACK,
Canada	Dr. D. W. R. MCKINLEY,
Czechoslovakia	Ing. P. BECKMANN,
Denmark	Prof. J. RYBNER,
Finland	Eng. P. MATTILA
France	Mr. B. DECAUX,
Germany	Dr. W. DIEMINGER,
India	Dr. MITRA,
Italy	Prof. G. RIGHINI,
Japan	Prof. I. KOGA,
Morocco	Dr. A. BENABUD,
Netherlands	Prof. B. D. H. TELLEGEN,
New Zealand	Dr. C. D. ELLYETT,
Norway	Prof. L. HARANG,
Spain	Father GALDON,
Sweden	Dr. H. STERKY,
Switzerland	Prof. D. TANK,
U. K.	Mr. J. A. RATCLIFFE,
U. S. A.	Mr. H. W. WELLS,
U. S. S. R.	Prof. V. B. ILYIN.

The following attended the session without voting power :

Honorary Presidents : Sir Edward V. APPLETON,
Dr. J. H. DELLINGER,
Prof. Dr. B. VAN DER POL.

Vice-Presidents : Dr. L. V. BERKNER,
Dr. C. R. BURROWS,
Dr. R. S. SMITH-ROSE.

Presidents and Secretaries of National Committees

Australia

President : Sir John P. V. MADSEN, Radio Research Board, c/o Electrical Engineering Department, The University, Sydney N. S. W.

Secretary : Dr. D. F. MARTYN, Radio Research Laboratories, Camden, N. S. W.

Austria :

President : Prof. Dr. Ferdinand STEINHAUSER, Direktor der Zentralanstalt für Meteorologie und Geodynamik, Wien XIX, Hohe Warte, 38.

Secretary : Prof. Dr. Otto BURKARD, Institut für Meteorologie und Geophysik, Universität Graz, 1, Halbärtgasse.

Belgium :

President : Mr. le Prof. DACOS, 196, rue des Vennes, Liège.

Secretary : Mr. le Prof. A. DORSIMONT, Laboratoire des Télécommunications, Ecole Royale Militaire, Bruxelles 4,

Canada :

President : Dr. J. S. MARSCHALL, Physics Department Mc Gill University, Montreal, 2., Qu.

Secretary : Dr. D. W. R. MCKINLEY, Radio and Electrical Engineering Division National Research Council, Ottawa, Ontario.

Czechoslovakia :

President : Mr. le Prof. Dr. Ing. J. STRANSKY, Narodni Komitét pro vedeckou radiotechniku pri narodni rade badetelské Ecole Polytechnique, Husova, 5, Praha I.

Denmark :

President : Prof. J. RYBNER, Professor of Telecommunications, Royal Technical University of Denmark, Øster Voldgade, 10, opg G, Copenhagen K.

Secretary : Eng. F. HEEGAARD, Statsradiofonien, Radiohuset, Rosenorns Allé, 22, Copenhagen V.

Finland :

President : Prof. V. YLÖSTALO, Professor of Radio Technique, Finland Institute of Technology, Helsinki.

Secretary : Dr. P. MATTILA, The State Institute for Technical Research, Albertinkatu, 40-42, Helsinki.

France :

President : Général A. ANGOT, 92, rue Brillat-Savarin, Paris 13e.

Secretary : Mr. J. VOGE, Ingénieur au Laboratoire National de Radioélectricité, 196, rue de Paris, Bagneux (Seine).

Germany :

President : Dr. W. DIEMINGER, Direktor, Institut für Ionosphärenforschung in der Max-Planck-Gesellschaft, Lindau über Northeim (Hannover).

Secretary : Dr. Ing. H. T. FLEISCHER, Fernmeldetechnisches Zentralamt der Deutschen Bundespost, Rheinstrasse, 110, Darmstadt.

Greece :

President : Mr. le Prof. Michel ANASTASSIADES, Directeur de l'Institut Ionosphérique de l'Observatoire d'Athènes, Ministère des communications et travaux publics, rue Voulis, 4, Athènes.

India :

President : Sir K. S. KRISHNAN, Director, National Physical Laboratory of India, New Delhi, 12.

Secretary : Shri M. H. ZINJANI, Under Secretary, Department of Scientific Research and Technical Education ; Ministry of Education and Scientific Research, New Delhi.

Italia :

President : Mr. le Prof. M. BOELLA, Istituto Elettrotecnico Nazionale « Galileo Ferraris », Corso Massimo d'Azeglio, 42, Turin 308.

Secretary-Treasurer : Dr. Alvaro DONADIO, Consiglio Nazionale delle Ricerche, Piazzale delle Scienze, 7, Rome.

Japan :

President : Dr. Issac KOGA, Electrical Engineering Department, Faculty of Engineering, University of Tokyo, Tokyo.

Morocco :

President : Mr. Jacques SABBAH, Directeur de Cabinet au Ministère des P.T.T., Rabat.

Secretary : Mr. BERRADA, Chef du Service Technique de la Radiodiffusion Marocaine, Rabat.

Netherlands :

President : Prof. Ir. B. D. H. TELLEGEN, Geulberg, 1, Nuenen.

Secretary : Ir. P. L. M. VAN BERKEL, Dr. Neher Laboratorium P.T.T., Leidschendam (Z. H.).

New Zealand :

President : Dr. M. A. F. BARNETT.

Secretary : Mr. G. J. BURTT, Secretary, Radio Research Committee, Dominion Physical Laboratory, Private Bag, Lower Hutt.

Norway :

President : Dr. Leiv HARANG, Norwegian Defence Research, Establishment Division of Telecommunications, Kjeller near Oslo.

Secretary : Eng. F. LIED, Secretary, Norwegian Defence Research Establishment, Kjeller near Oslo.

Poland :

President : Dr. Janusz GROSZKOWSKI, Vice-President, Polska Akademia Nauk, Warsaw.

Secretary : Mr. l'Ing. K. BOCHENEK, Polska Akademia Nauk, Palaz Kultury i Nauki, Warsaw.

Portugal :

President : Mr. le Prof. H. AMORIM FERREIRA, Servico Meteorologico Nacional, Largo de Santa Isabel, Lisboa.

Spain :

President : Général du Génie Excm. Sr. D. Carlos MARIN DE BERNARDO, Chef de Transmission de l'Armée.

Secretary : Mr. J. M. TORROJA, Serrano, 123, Madrid.

Sweden :

President : Dr. H. STERKY, Director General, Royal Board of Swedish Telecommunications, Stockholm.

Secretary : Eng. S. GEJER, Director of Department Royal Board of Swedish Telecommunications, Brunkebergstorg, 2, Stockholm, 16.

Switzerland :

President : Dr. W. GERBER, Direction Générale des P.T.T., Speichergasse, 6, Berne.

Secretary : Dr. N. SCHAETTI, c/o Paillard, Yverdon.

Union of South Africa :

The Secretary-Treasurer : South African Council for Scientific and Industrial Research, P. O. Box 395, Pretoria, Tvl.

United Kingdom :

President : Mr. J. A. RATCLIFFE, Cavendish Laboratory, Free School Lane, Cambridge.

Secretary : Dr. D. C. MARTIN, Assistant Secretary, The Royal Society, Burlington House, London W.1.

U. S. A. :

President : Dr. W. E. GORDON, School of Electrical Engineering Cornell University, Ithaca, New York.

Secretary : Dr. S. SILVER, Division of Electrical Engineering University of California, Berkeley 4, California.

Executive Secretary : Mrs Helen E. HART, U. S. A. National Committee of U.R.S.I., National Research Council, 2101, Constitution Avenue, N. W., Washington, 25, D. C.

U. S. S. R. :

President : Academician A. I. BERG, Academy of Sciences of U. S. S. R., Moscow K. 9.

Yugoslavia :

Secretary : Mr. le Prof. Ing. Al. DAMIANOVITCH, 6, Stevana Sremca, Beograd.

Plenary Opening Session

August 26th, 1957

Call to Order by Mr. H. W. Wells,

Chairman of the U. S. A. National Committee

Mr. President, ladies and gentlemen,

On behalf of the U. S. A. National Committee, it is my privilege to call to order this meeting of the XIIth General Assembly of the International Scientific Radio Union.

We are honored today in having with us several special guests; these are :

Dr. W. W. Atwood, Jr., Director, Office of International Relations, National Academy of Science-National Research Council.

Dr. John T. Henderson, President of the Institute of Radio Engineers, and also a member of the Canadian Delegation.

Dr. E. Metzler, Director of the C.C.I.R.

Dr. Ray Zwemer, who is representing the Director General of Unesco.

Before we proceed with the formal addresses scheduled for this morning, I wish to make a statement of acknowledgement and to introduce our special guests for the opening session. I am certain you all realize that the preparations for an undertaking of this nature require substantial amounts of (1) facilities, (2) manpower and (3) money. Time does not permit individual acknowledgement of the many contributions in all three categories which have made possible the successful and extensive arrangements for this meeting. In particular I call to your attention the statement of acknowledgement in the back of your official red program.

We were especially fortunate in having the services of Dr. J. H. Dellinger as Chairman of the General Arrangements Committee. His personal devotion and guidance to others working with him have been key factors leading to a successful meeting. Dr. Dellinger, would you kindly stand up (Applause).

Also, here in Boulder, the Local Arrangements Committee operating with K. A. Norton as Chairman has handled a multitude of details necessary to the meeting preparations. He has had the generous cooperation of many individuals in this area. Mr. Norton, would you kindly stand up ? (Applause).

We may now proceed with the scheduled addresses as indicated in your program.

Address delivered by Mr. Quigg Newton,

President of the University of Colorado

Ladies and Gentlemen,

I consider it a great privilege to be invited here, to welcome you to Boulder, and to extend to you the cordial greetings and good wishes of the University of Colorado, which I have the honor to represent.

We have looked forward to your coming for many months. If I am not mistaken, the first meeting of the local arrangements committee was held here more than two years ago, and I am sure that the General Arrangements Committee, under the extraordinarily able direction of Dr. Dellinger, has been at work for a much longer time perfecting the complex and detailed arrangements for this great international assembly.

I think there could be no more appropriate time to express to Dr. Dellinger, Mr. Shapley and the other members of the General Arrangements Committee, and to Dr. Brown and his dedicated staff at the Boulder Laboratories of the National Bureau of Standards, the appreciation of the University of Colorado and of the Boulder Community for their magnificent efforts in planning local arrangements for this Assembly ; and I want to say to them that we are deeply grateful.

And I should like to say to you, the delegates and observers of this Assembly, that we very much appreciate your presence here. You have come to Boulder from all parts of the world to participate in discussions of scientific importance. By coming here, you have brought this community into focus, for the eyes of the world, as an important scientific center.

Because this Assembly is of momentous importance to all the world, I feel that every moment of your deliberations is precious and I shall not intrude longer on your time.

I simply want to say, in closing, that we welcome you to Boulder and to the University of Colorado, not only as distinguished scientists whose good will we value highly but also as friends and world neighbors.

I trust that your stay here will be most enjoyable and profitable, and that when you leave, to return to your homes, you will carry with you pleasant memories of the University of Colorado and of the city of Boulder.

Mr. Leo C. RIETHMAYER, Mayor of the City of Boulder then welcomed the attendants to the meeting and expressed his warmest wishes for the success of the meeting.

Greetings from Dr. F. W. Brown,

Director, Boulder Laboratories, National Bureau of Standards

Dr. Lejay, Ladies and Gentlemen,

Mr. Riethmayer and Mr. Newton have expressed the sentiments felt by the hosts, on behalf of the Director, Dr. Astin, for the National Bureau of Standards and particularly as a representative of the staff of that part of the Bureau located here in Boulder, I wish to extend our warmest welcome to the delegates and their families on the occasion of this XIIth General Assembly of U.R.S.I. Needless to say the members of the staff of the Central Radio Propagation Laboratory and the Radio Standards Laboratory here have been looking forward to and preparing for this occasion for the past two and one-half years.

The study of radio waves is one of the sciences in which it is absolutely essential that the scientist have access to the knowledge of the earth and its atmosphere and the effects of these media on radio propagation on a world-wide basis and not just within his own national boundaries. Hence, international cooperation and international meetings such as this one are the « life-blood » of the progress in radio science.

One of the things that impressed me most when I came into this work about 3 ½ years ago was the extent of the measurements and other information gathering activities on a world-wide scale that were required to do our job — and the high percentage of world travellers in our staff. Some of our people are practically global commuters.

Now a large segment of the radio science of the world has come to Boulder for this meeting — and we are very proud of this fact. Our radio people will derive invaluable inspiration from their association with this group of the world's ablest radio scientists. Also, having so many families here will add to the pleasure of the occasion.

We will all reciprocate by doing our utmost to help all of the people of Boulder make your stay here enjoyable and profitable, realizing that the effort thus required will be repaid many times over.

Thank you.

Address of Welcome by Detlev W. Bronk,

President, National Academy of Sciences and Rockefeller Institute

It is my pleasant privilege to extend the welcome of the National Academy of Sciences of the United States to so many of our friends and colleagues from so many other countries. We are grateful to you for having come so far to share with us your friendship and your knowledge. We appreciate the especial honor you have done us by coming during this momentous year of international cooperation for the furtherance of geophysics.

If we can make your visit intellectually profitable and socially pleasant, it will be a small symbol of our great gratitude for your hospitality and friendship of other years in other places, for the inspiration of ideals that we hold in common, for the benefit of shared knowledge.

I wish I had the power to put in adequately expressive words the especial reasons why the friendly associations of international gatherings such as this give Americans so much pleasure. It is in part, I think, because we are so recently come from your native lands. Our nation has been made by those who were brothers of your fathers. To your countries we are indebted for Alexanderson and for Pupin, Steinmetz, Tesla and Zworykin to mention but a few who are best known to you. Your ancestors were our ancestors too.

Our feeling of friendly kinship is due in part, I further think, to our common cultural heritage. The first visit of an American to your country, or to yours, is a remarkable experience, for one has the bewildering feeling that one has seen it all before. And so one had through the eyes and words of those who wrote the literature of your country, which was the literature of our fathers on which we too were reared.

Another deeply-rooted reason for our feeling of close association with you is the recent growth of science in this country from the seeds brought by our teachers who first studied in your lands. At a time when scientific investigation was just beginning here, Benjamin Franklin was encouraged by election to the Royal Society of London, the Royal Academy of Science at Göttingen, the Academies of Sciences of Paris, of Padua and of St-Petersburg. From those days of Franklin until now we have a deep debt of gratitude to you for first nurturing those who then developed science here.

And so I say our warm welcome has natural roots in traditions and brotherly associations which we hope you of our mother countries may understand.

Because a scientist is necessarily a partner of many others, our early predecessors organized associations such as yours for the exchange of information, the catalysis of ideas and for cooperative effort. Even at the beginning of the modern scientific era it was realized that to be an isolationist in science handicaps

one's efforts. Thus the oldest ancestor of our Academy, the Academia dei Lincei of Rome, as early as 1609 laid plans to establish « non-clerical, scientific monasteries for scientific cooperation... In each house every observation and every discovery was to be communicated without delay to the head house and to all the sister houses. »

From such desire to learn from others and to communicate to others one's thoughts and observations there developed the international spirit of science. Like traders for rare goods, scientists have sought new ideas and newly discovered knowledge wherever they could be found. Such objectives were set forth by Francis Bacon in his description of « The House of Solomon. » He proposed that there be twelve scientists of that House who should go from country to country for the exchange of knowledge derived from experimental investigations. Significantly, Bacon said those twelve should be called « Merchants of Light. »

In fulfillment of the Baconian ideal, you are modern Merchants of Light. I do not say this lightly. In these dark days of world discord and rising barriers to free communication, every gathering such as this is a significant breach in the walls of silence that separate common people of good will. People would be united by shared knowledge and mutual understanding were they able. Gatherings such as this nurture the awareness of statesmen that, through science, nations can peacefully gain those material benefits which they have sought fruitlessly to acquire through war.

Science has no unique power to create a more peaceful world. But science has in the past liberated men from the uncontrolled domination of natural forces and from ignorance and superstition. It gives promise of freeing men from the control of human force and the imagined necessities for greed and conflict by increasing their intellectual and material welfare. If this be the worldwide goal of scientist, there must be freedom for scientific effort, unrestricted by the boundaries of nations and unlimited by selfish national interests.

This year was chosen as the International Geophysical Year for scientific, solar reasons. But it is timely, too, for international reasons. The example of scientists of many nations working together in cordial cooperation for common aims is a heartening

example of what could be a more general pattern of international amity.

Nations have often cooperated in mobilizing their resources for attack against other nations or for defense against aggression. But never before have all the major nations of the world mobilized their resources in a common undertaking for the peaceful benefit of all. The significance of this friendly cooperation will, I think, equal the greatest scientific discovery that may be made during this momentous year.

Scientists are uniquely fitted to persuade their fellow citizens that shared knowledge increases the intellectual resources of every nation and relieves the necessity of conflict for material resources. A discovery of human value usually depends on previous research carried on in many other countries ; it is of benefit to the people of all countries. The observations of Gallileo and Copernicus and Newton, as you well know, have extended the intellectual horizons of people in every nation. But the present resurgence of selfish nationalism is in direct conflict with that spirit of science.

The broader vision of a great statesman was voiced by Lord Bryce forty years ago when he was Ambassador from Britain to this country. Said he then :

« One of the most delightful things of science is that it knows no allegiance to nationality. Science is a republic in which there is no passport to greatness, except service and genius. It is a republic of which everyone is a citizen and where everyone has equal rights in every part of the world... I have veneration for your lofty and disinterested spirit. I have fear for the enormous power you exercise. »

The enormous power Lord Bryce feared has indeed been prostituted by those who use the fruits of science for their selfish ends. Science gives man awful power over men as well as nature.

The greater power over man and nature provided by science makes necessary more knowledge and greater wisdom in order that we may control and use our greater power for man's welfare. Science gives us the building stones of a better world, but the world will be as we choose to make it.

In a unique way you of this union diffuse the knowledge, and thus foster the wisdom, necessary for the building of a better world. Radio has profoundly increased the scope of man's mind

and the range of his senses. It offers challenging, undeveloped possibilities for communication between peoples and for their better understanding of science which is rapidly reshaping the world in which we live. But you have also made possible domination of the minds of many by a few. You have presented mankind with an opportunity and a challenge. Unless the beneficient power you have provided is wisely used, the peoples of the world will be torn between those who know and those who do not know. No nation and no culture can long survive half free to know, half slave to ignorance and superstition.

Every civilization has been the product of men's minds. The more there were who had the gift to wonder and the desire to know and understand, the more vital was the civilization.

I sometimes fear that scientific knowledge and its applications increase so rapidly that the imagination is dulled and the ability of men to marvel and to wonder is weakened by a surfeit of scientific wonders. As scientists, it is our duty to keep alive the spirit of intellectual adventure. If science is revealed as a great odyssey of the human spirit, man's understanding will be increased and his spirit quickened. Curiosity and the ability to wonder stimulate the mind of man and lead him on toward his divine destiny.

Your modesty and the nature of your daily work may hide from you the marvels of your achievements. But as a biologist I can marvel at the way in which you have, increased countlessfold the range of man's normal speech and hearing and of vision. By radio you have made possible swift transportation beyond the speed of birds. These are achievements that should arouse the spirit of wonder in people everywhere who in humility marvel at the ability of man to increase his power and stature without limit.

The practical uses of those achievements have transformed the pattern of man's lives and habits. But the significance of your achievements is far greater. Yours has been a great adventure of the human mind on the frontiers of knowledge.

Response of Father Lejay

President of U.R.S.I.

(*Translation*)

We are honored by your decision to come to Boulder to preside at the opening of our XII[th] General Assembly, and the International Scientific Radio Union appreciates your presence. It is my very pleasant task to express gratitude to you and to the National Academy of Sciences on behalf of my colleagues.

High officials of a Nation have given us assurance of their support in the past ; however, today we are grateful for the presence of a distinguished scientist representing an institution which is universally recognized.

We are extremely flattered that you should have found time to come to this meeting when you are burdened with the most extensive responsibilities concerned with the development of science in the United States ; just as we are grateful to President Newton for the generous hospitality of this wonderful university, to Doctor Brown, Director of the Laboratories of the National Bureau of Standards at Boulder, and to Professor Riethmayer, Mayor of Boulder.

The assurance of interest of so many distinguished authorities provides encouragement to U.R.S.I. to continue in its efforts in the tasks it is pursuing.

« To develop, on an *international basis*, *scientific* studies pertaining to radio ; to promote and organize and discuss *researches requiring international cooperation* », such are the essential aims of our Union and the only reason for its existence.

In an era when profound changes are wrought in the evolution of techniques (and the techniques of radio do not lag), when fields of research which were reputed sterile only yesterday suddenly reveal an extraordinary fertility, when the number of specialists interested in our problems increases exponentially, we ought perhaps to examine whether our traditional activities still answer the needs of our times, and whether we should not undertake some adaptations. But in order that such an evoluton may occur without endangering proper continuity with the work already accomplished, our sights must remain fixed on the two leading

ideas which have always defined the orientation of our work ; it is imperative that, to faithfully fulfill its role, U.R.S.I. retain its *international* character, in a world where « politics » now and then are shaken by violent up-heavels ; and to remain itself it must keep its strictly *scientific* character in a world where « economics » urge the development of technology with almost explosive violence which tends by its brilliance to dim the clear light of pure research

I have no doubt, Mr. President, that our fidelity to these principles will meet with your distinguished approval. Surely you will rejoice at the thought that there are in the world some organizations where representatives of all nations are led, in the natural course of their activities, to aid the progress of human relations by pooling their intellectual resources. Does not our Union follow the same direction which the Academy of Sciences has taken, and which is so highly appreciated in the United States ?

In this direction we may claim that the U.R.S.I. has played a pioneer role and that it has not failed in spite of obstacles which the very nature of our researches could not but make more formidable. The direct applications of discoveries in radio are of extreme importance, both as to the extensive industrial developments they make possible and as to their repercussions in the field of telecommunications and in many other fields.

Industrial research can bring so much to science that we must keep very closely in touch with the laboratories of great companies. Indeed, and we must honor them for it, industrialists who join us in our Commissions and General Assemblies have always been most careful to keep to the scientific aspects of the problems, leaving aside their own specific concerns. Thus there has never been any danger of not maintaining our Union in the field of pure research.

The U.R.S.I. has not been any less faithful in keeping its *international* character. From its earliest beginnings our policies have been conceived in such a way that each nation has the possibility of expressing its views with complete freedom. Thus a family spirit has found many opportunities to manifest itself concretely in joint enterprises ; if we want an example of this, let us recall simply that U.R.S.I. is probably the only scientific union to dare entrust to international committees the task of preparing up-to-date digests on new problems, and to publish such Special Reports

under an international hallmark. Need we mention how effectively such work can strengthen the ties between the authors of different nationalities, and at the same time make certain of an exceptionally rich literature ?

It is a fact that the need for exchanges between researchers of varying origins becomes every day more imperative. Thus, in the last few months, several symposia on specific questions have been organized under the felicitous initiative of several National Committees, at the initiative of the Union ; thus very laudable competition has been created ; these meetings are so successful that we may wonder whether we may not have to take some measures to keep them from multiplying and becoming too absorbing. In any event, they are witness to the desire and need of establishing contacts between specialists. No one will deny that this result is promoted by the evident efficiency of the contacts during our General Assemblies.

Another form of international activity is developing today in many other scientific Unions : it may not be without value to give it some attention ; I am thinking of the Permanent Offices which in recent years have developed in a Federation of Unions and which receive financial help from Unesco through the Council of International Scientfic Unions. In the eyes of the leaders and councils of the various Scientific Unions, one conclusion was evident : the role of these Unions could not be limited to the discussions of problems during General Assemblies ; their activity must be continued between the General Assemblies, when the work on the problems is developing.

It often happens that the progress of knowledge requires that observed data be continuously assembled and compared and placed at the disposal of numerous specialists in order to aid researches, often extensive and of complex nature. *Discovery, often of individual origin, becomes in the natural course of things, a sort of collective wealth which must be exploited by international cooperation.*

In many cases the pursuit of research could not be continued effectively without some *organization*, and this is the reason why each Permanent Office is under the authority of an International Committee and a Director appointed by the Union.

In an era when scientific data accumulate in all fields of knowledge, we may well wonder whether these Permanent Offices are not our only chance of progressing « when the trees are so numerous that they hide the forest », that is, when the accumulated mass of data prevents any general view. Isn't this precisely the case of several of our branches of science ? Observations on the ionosphere for example have reached such a high degree of perfection that it will probably be difficult to go beyond it. The number of soundings made every day increases ceaselessly, the analysis of the data becomes more complex as the known phenomena become more numerous. Considerable work has already been under way in this direction, and is made more coherent by the wise decisions of one of our Commissions. Yet it remains desirable to organize more detailed diffusion of knowledge, easier access to documents, and plans for more general studies. It appears to be the role of our Union to place all the data at the disposal of researchers, in the same way, for example, that the International Union of Geodesy and Geophysics handle seismic records and magnetograms. Thus our investigation of the ionosphere would receive a fresh impulse.

It would be easy to mention other techniques, already well advanced and partly stabilized for which, in the near future, similar organizations would also appear necessary.

Along such lines, the activity of the U.R.S.I. would continue to develop in the interval between our General Assemblies ; the Union and its Commissions would find there a source of renewed vitality for the greater benefit of science.

These considerations on the aspects of our international activities bring me to discuss the role which the Union has already played, and will go on playing even more, in the organization of various investigations during the International Geophysical Year.

While the initial idea of a Geophysical Year did not come from the U.R.S.I., no one will deny that our Union has had a predominent role in the development of this project, and everyone agrees on the prediction that its activities will prove very important when the data are interpreted.

This is quite natural, of course, because the fundamental aim of the Geophysical Year is to obtain, through the cooperation of all nations, through the coordination of all their efforts, some general

views on the great problems of geophysics, and it is evident that nowhere could this be more profitable that in the field of ionosphere research, and in the study of storm disturbances. In these fields, considerable data have already been gathered but they give us but scattered views of the phenomena concerned. The results already obtained suggest studies which in turn require additional *coordinated information.*

This need has been deeply felt ; it has already received concrete fulfillment in the considerable effort of some of the most eminent of our colleagues, to whom we must do homage : the programs of observations which they have planned are at present put into effect in over 200 sounding stations, and in about 40 stations for the measurement of absorption and ionospheric winds, scattered throughout the Globe.

Let us add that for the first time in the history of such enterprises, it has been planned that the programs of observations would be essentially variable depending on circumstances. Instead of preparing an inflexible plan which would have demanded too prolonged work from the observers, and resulted in wasting their effort, it was agreed that the observations should be restricted to the most interesting periods, for instance during the course of magnetic storms. Such a decision, simple in appearance, required for its efficient implementation a powerful organization of the forecasting and radio communication services.

Thanks to the efforts of several persons, whose devotion must be mentioned, thanks also to the generosity of the communication services, to whom we publicly express our gratitude, this organization is assured today of functioning impeccably, and the output of the Geophysical Year will thereby be increased tenfold.

Undoubtedly, the technical preparation for such a vast enterprise has been a complete success, and the U.R.S.I. has good reason to rejoice in having thus fulfilled a necessary role.

But its action is not ended here ; after winning the war, we must tomorrow win the peace.

Yet it must be confessed that while three years ago it seemed difficult to organize a coherent program, to mobilize the specialists of so many different nations, to find funds and executive personnel, it appears today that the exhaustive exploitation of the results will meet with much greater practical as well as moral obstacles.

The Geophysical Year would not be successful, obviously, if it led only to the gathering, even on a colossal scale, of observed data. The work will be completed only if such data are effectively made available to young researchers who will find among them the subjects of new intellectual pursuits. While the Geophysical Year could be considered as an end in itself as long as the work consisted in organizing planned observations, from now on it must be a starting point on the road to discovery ; and here evidently, a new spirit must arise. One step forward, a difficult step, must be made in the field of international cooperation, not on the practical level but on the higher plane where intellectual resources are pooled. At once, moral difficulties will arise which have not been encountered in the organizational phase.

Indeed, while each nation, and within each nation, each institution, agreed to share in the responsibilities for making observations during the I.G.Y., it nevertheless retained its autonomy. On the contrary, in the distribution of data, and in the organization of their use, some will be requested to give to others, (and often gratuitously and without hope of any returns), some results often obtained at the cost of great efforts. I wonder whether this disinterested attitude, deeply valued by numerous men of science who are more anxious to increase their knowledge than establish their own reputation, will spread to the point where it will do away with the rivalries, honorable rivalries to be sure, which exist between nations. *What I do know is that in the present condition of science such an exchange is the necessary condition to any progress.* It is best to believe, I am sure, that the success already obtained when the Geophysical Year was organized, reinforced by the success which we have a right to expect in the gathering of observations, will be sufficient to create or maintain the necessary enthusiasm for the joint exploitation of the results. Allow me to believe that our Union must take the needed initiative to make sure that this essential goal is reached. Its ancient traditions, the spirit of collaboration which has always been the rule among its members, the courtesy which has always marked our Assemblies, the broad scopes which have always been emphasized in them will all contribute to create a favorable climate for the realization of our joint endeavor.

But this is not all. There is another direction in which our

Union can have an effective influence. Under the force of circumstance, the Geophysical Year has been built somewhat like a machine ; the programs have sometimes been set up in a rather rigid manner ; and of course there are some advantages to this. A discipline almost military in character is needed for the implementation of vast operations which mobilize numerous and diverse resources ; but it runs the risk of killing individual initiative. Given orders to follow a detailed plan and to gather data in a standard form, the observers may fear that they are working for the benefit of some Lords of Science ; they may then feel mercenary. If, by some misfortune, such were the case the results of the Geophysical Year would be reduced to cold statistical conclusions ; science would turn its back on culture. This must not be. No effort must be spared to insure that, in the general frame of a coherent program, the activity and initiative of young observers shall develop in complete freedom, that what genius is scattered over the world shall not be smothered but on the contrary provided with an atmosphere where it can appear and be nurtured, that years of laborious efforts of observation shall prepare and facilitate the few hours of synthesis which in the end are the true values of Science.

The U.R.S.I., in acting in this direction, need not betray its past.

I will no doubt speak for all our colleagues foreign to this country in expressing what they have already felt implied in my words throughout this address, namely in mentioning the immense part played in the achievements of the U.R.S.I. by our American colleagues. I am happy to have this exceptional occasion to honor publicly not only the incomparable technical value of their role in the work of every one of our Commissions, but also the contribution they have always made to the successful operation of the Union and the formation of the spirit of collaboration which I have spoken of.

To go into details would mean repeating everything I have said, chapter by chapter, and inserting the names of people. Without going as far back in the past as the foundation of our Union, permit me to underline how our Vice-Presidents, Dr. Berkner, and Dr. Burrows, who we see with regret moving away from our field of activity, have participated in the work of our Union.

Time does not permit me to mention all those who have played an important role in the administration of the Union. If I had to recall the names of all who have brought fame to the Union by their works, the list would be extremely long ; it will be lengthened even more during the course of this Assembly as we well know. May I be permitted to express our admiration for these pioneers who have opened so many new paths in science, and who have always so graciously given us leave to profit by theirs discoveries. Let me tell them that while in each of our meetings we have profited by their techniques, spirit of initiative, their optimism, today our pleasure is increased at the thought of seeing their very fine accomplishments in this city.

Our very presence here is an indication of the homage which the U.R.S.I. wished to render them. The number of people who have wanted to be associated in this homage, coming from so many countries, some of them very distant, shows with what high and just esteem we look upon the work carried out in this country, and in what great and universal respect we hold our American colleagues.

I have kept to the last a name which will often come into our minds during this General Assembly, whose organization appears so perfect but has not been achieved without extraordinary effort. It is fitting to congratulate and thank right now the man who, for two years has given of himself ceaselessly as head of the Organizing Committee, our Honorary President, Dr. Dellinger. I congratulate also his immediate associates in the organization of this assembly : Mr. Norton and Mr. Shapley who have perfected the arrangements for the meeting, and Professor Gordon and Mr. Wells who have provided valuable aid to our colleagues in arrangements for their visits to this country.

We do hope that their efforts receive the reward that is rightfully theirs : that of continued success. This hope has already been fulfilled. We are already assured of finding at Boulder not only a functionally efficient organization, but, what is even more rare, a fellowship of peerless cordiality.

The General Secretary's Report

Mr. President, Ladies and Gentlemen,

The year 1957 marks an important stage in the history of U.R.S.I. not only because it coincides with the opening of the International Geophysical Year, but also because after 30 years the Union has returned to the United States where our second General Assembly was held, in Washington. This was the first Assembly for which a printed Report was issued.

Three of our Honorary Presidents who are present at the XIIth General Assembly were also present in Washington, they were : Sir Edward Appleton, Dr. J. H. Dellinger and Professor B. van der Pol. Their presence here is a proof of their attachment to U.R.S.I.

Nine of the eleven National Committees that were in existence at that time were represented at the Washington Assembly, where sixty people were present.

Since then, despite the apparent inactivity during the Second World War, U.R.S.I. has come a long way : during this Assembly the number of National Committees will be brought up to twenty seven. Whereas in 1927 the scientific activities were in the hands of four Commissions, to-day U.R.S.I. includes seven to which have been added the U.R.S.I. Commission for the I.G.Y. ,the Permanent Ursigram Committee, the Working Committee for the C.C.I.R. as well as numerous sub-commissions.

During the Assembly the Presidents of these groups will make reports on their past, present and future activities.

Finance

Although it is our intention that this report should be as brief as possible it must also be complete and we must therefore mention finance.

The financial situation is excellent and gives every satisfaction for two reasons. First of all the regularity with which the National Committees pay their subscriptions, and we are very happy to be able to thank them officially, the second reason for our prosperity lies in the subsidies which we receive from Unesco.

It is thanks to this organisation that since 1947 we have been able to restore our finances on a sound basis after the difficult period resulting from the war years.

The management of our finances is the subject of a detailed report presented to the Finance Committee. This Committee will examine the report and make known its conclusions at the final session of the Assembly. At this session the General Assembly will be asked to approve the accounts of receipts and expenses ; a decision must also be taken concerning the proposal for the modification of the scale of subscriptions which will be submitted by the Executive Committee.

Administration

It would appear unnecessary to insist on the importance of the work entrusted to the General Secretary ; it is sufficient to enumerate the tasks which the Statutes and the Bylaws place in his charge. Each time that the number of National Committees increases, each time that some new activity is undertaken by U.R.S.I., the responsability and the work of the General Secretary increase also, sometimes very slightly but sometimes in a very marked degree.

Among the tasks within the General Secretary's province mention should be made of the publications which have become more and more numerous throughout the period of U.R.S.I.'s existence.

In the coming weeks U.R.S.I. will publish a detailed Alphabetical List of Ionospheric Stations, for which a very considerable amount of material has been collected and is ready to be sent to the printer. In addition there will be the publication of the Information Bulletin and the Reports on the General Assembly.

Organisation of the XIIth General Assembly

It was feared that the organisation of this Assembly might prove rather difficult on account of the distance of the meeting place and unforeseeable circumstances. However, thanks to the efficient help of the « General Arrangements Committee », under the chairmanship of Dr. J. H. Dellinger, the General Secretary's task has been made very easy and he wishes to thank all the Members of the Committee, he regrets that it is not possible to mention each one individually, but he requeests their President to be so kind enough as to convey to each member of the Committee his warmest thanks for all the help they have given.

Recommendations for the presentation of reports and individual communications were sent out in due time but, unfortunately, too many of the people concerned have not followed these directives which risks causing « disturbances » not to say « fade outs » in the distribution of the documents. Neither Commission III nor Commission IV can be asked to undertake the examination of possible remedies for this state of things and, during this Meeting we must endeavour to find a way by which these « disturbances » and « fade outs » can be avoided or decreased.

Conclusion

Before I close, I wish to tender my warmest thanks to : Father Lejay, President of the Union, for the wise and kind advice he has given me during his term of office, and to the Members of the Bureau for all the help they have given me, also to all those, too numerous to mention, the Presidents, Secretaries of Commissions and Sub-Commissions, Presidents and Secretaries of National Committees, etc... who have given their help so that the work of U.R.S.I., and especially the work of this General Assembly, might be carried out in an atmosphere of cordiality and friendship, which has always been, and must remain, one of the characteristics of U.R.S.I.

Highlights of Commission Technical Programmes

The Commission Chairmen are then invited to provide highlights of Commission Technical Programmes during the General Assembly. These statements are published in the Parts of this Volume devoted to activities of each Commission.

Telegram of Welcome

The following telegram addressed to the President of U.R.S.I., was received at the opening of the meeting : « As Governor of Colorado, I am very happy to join with the National Bureau of Standards in welcoming the members of the International Scientific Radio Union to Boulder and to Colorado for your XIIth General Assembly.

We are proud of the fact that with the Bureau of Standards located here, along with the University of Colorado, and all its facilities we have become an important center of scientific research.

We feel greatly honored that the first meeting of your organization in the United States since 1927 is being held in our state.

You have come here from all over the world as leading scientists in the field of radio. I know you will all benefit greatly from an interchange of scientific and technical knowledge. I trust you and all the nations you represent benefit to an equally great extent through an exchange of friendliness and international good will.

I hope that while you are here you take advantage of Colorado's beautiful scenic drives and outstanding recreational opportunities. Best wishes for a successful meeting and pleasant visit.

Steve McNichols,
Governor of Colorado.

List of Reports and Papers submitted to the General Assembly

E = Original text in English.
F = Original text in French.

N°	Commission	Country	Titles and Authors
1	I to VI	General Secretariat	C.C.I.R. Findings of interest to the U.R.S.I. (E).
2	V	—	Report from Sub-Commission V*a*, on the continuous 24 hour survey of solar radio emission, A. H. DE VOOGT, Chairman (E).
3	IV	U.S.A.	Periodic Dawn Chorus, H. E. DINGER (E).
4	IV	U.S.A.	The computation of ionospheric reflection coefficients from the waveforms of sferics, A. G. JEAN, L. J. LANGE, J. R. WAIT (E).
5	VI	France	Contribution to the study of optical noise; Comparison with noise in radioelectricity, A. BLANC-LAPIERRE Professor at the Faculty of Sciences Algiers (F).
6	VI	France	Considerations on the notion of instantaneous frequency of a signal (F).
7	VI	France	Study on the notion of instantaneous power spectrum, A. BLANC-LAPIERRE and B. PICINBONO, Laboratory of Theoretical Physics, Faculty of Sciences, Algiers (F).
8	VI	France	Cascaded binary channels, J. LOEB (F).
9	VI	France	On the Babinet's theorem in the magnetic theory, P. PONCELET (F).
10	VI	France	Topological methods applied to electronics (F).

N°	Commission	Country	Titles and Authors
11	VI	France	Determination of the type of emission producing minimum interference, Report submitted to the 1956 Plenary Assembly of C.C.I.R. (E).
12	VI	France	On the determination of the inverse random function's spectrum and its applications, R. FORTET, Laboratoire Central des Télécommunications, Paris (F).
13	VI	France	Instantaneous spectrum and signal analysis. Applications to transmission problems in communications, P. DEMAN (F).
14	V	Belgium	Radio astronomical activities in Belgium and in the Belgian Congo, R. COUTREZ (F).
15	II	Japan	VHF propagation tests on over-mountains paths, I. MURAKAMI (E).
16	II	Japan	Theory of tropospheric propagation near beyond the radio horizon, O. TUKUSI (E).
17	II	Japan	Multi-path transmission through the Troposphere, T. OMORI (E).
18	II	Japan	Ray theoretical analysis of fading due to duct, F. IKEGAMI (E).
19	II	Japan	Multiple diffraction of electromagnetic waves by spherical mountains, K. FURUTSU (E).
20	II	Japan	On the relationship between the scattering of radio waves and the statistical theory of turbulence, K. TAO (E).
21	II	Japan	Characteristics of radio waves diffracted by a mountain, T. KOONO, Y. KURIHARA, M. FUKUSHIMA (E).
22	II	Japan	A new type refractive index variometer, K. HIRAO (E).
23	III	Japan	Dynamical structure of the ionospheric F2 layer as deduced from its daily variations, T. SHIMAZAKI (E).
24	III	Japan	On the occurence of the F1.5 at Tokyo, I. KASUYA (E).

N°	Commission	Country	Titles and Authors
25	III	Japan	Some results of a sweep-frequency propagation experiment over a north-south path at a distance of about 1000 km, Y. AONO and I. KURIKI (E).
26	III	Japan	Measure of magnitude of sudden ionospheric disturbance, Y. NAKOTA (E).
27	III	Japan	On radio propagation disturbances, K. SINNO (E).
28	III	Japan	Ionospheric F2 disturbances associated with geomagnetic storms, T. SATO (E).
29	II	Japan	Wave propagation over irregular terrain, K. FURUTSU (E).
30	III	Japan	On sequential *Es*, S. MATSUSHITA (E).
31	III	Japan	Remarkable lateral deviation in the ionospheric propagation, K. MIYA, M. ISHIKAWA, S. KANAYA (E).
32	III	Japan	A new theory of formation of the F2 layer, T. YONEZAWA (E).
33	III	Japan	Magneto-hydrodynamic waves in the ionosphere, S. AKASOFU (E).
34	III	Japan	Calculation of the propagation path of whistling atmospherics, K. MAEDA, and I. KIMURA (E).
35	III	Japan	The difficulties in explaining the formation of the ionosphere, Y. INOUE.
36	IV	Japan	Field-changes due to the lightning discharges and their discharge mechannisms, N. KITAGAWA (E).
37	IV	Japan	Lightning mechanisms and radiation atmospherics, H. ISIKAWA (E).
38	IV	Japan	The waveforms of atmospherics in the Far East, A. KIMPARA (E).
39	IV	Japan	Some results of simultaneous measurements of atmospheric noise in high frequency band, A. KIMPARA, H. SHINKAWA, T. FUJITA, Y. AONO, Y. TAKI, F. MINOZUMA (E).
40	IV	Japan	Measurement of amplitude probability distribution of atmospheric noise in high frequency band, T. ISHIDA (E).

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41	IV	Japan	On an investigation of whistling atmospherics in Japan, A. KIMPARA, A. IWAI, J. OUTSU (E).
42	V	Japan	A multiphase radio interferometer for locating the sources of solar radio bursts, T. HATANAKA, S. SUZUKI (E).
43	V	Japan	Emission mechanism of polarized solar radio bursts, T. TAKAKURA (E).
44	V	Japan	The position and size of the source of the most intense solar-noise burst on February 23, 1956, at a frequency of 4000 Mc/s, H. TANAKA, T. KAKINUMA (E).
45	V	Japan	Direct measurements of polarization of the radiation from individual radio Spot at a frequency of 4000 Mc/s, H. TANAKA, T. KAKINUMA (E).
46	VI	Japan	On the capacity of a noisy continuous channel, S. MUROGA (E).
47	VI	Japan	On the capacity of a discrete channel, Part II. Mathematical expression of the capacity of a noisy channel which is expressible by corresponding two multistage diagrams, S. MUROGA (E).
48	VI	Japan	Double sampling theorems in continuous signals, N. HONDA (E).
49	VI	Japan	Transformation of probability distributions and its application to compandor system, H. MINO (E).
50	VI	Japan	The parametron, an amplifying and logical element using varying-parameter resonators, H. TOKAHASHI, E. GOTO (E).
51	VI	Japan	General solutions of the logical algebraic equation with many unknowns M. GOTO (E).
52	VI	Japan	Theory of negative impedance converter, H. HIRAYAMA (E).
53	VI	Japan	The expansions of electromagnetic fields in cavities, K. KUROKAWA (E).

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54	II	Japan	Propagation of electromagnetic waves over mixed paths, K. FURUTSU (E).
55	VI	Japan	On the transition from a ground return circuit to a surface waveguide, H. KIRUCHI (E).
56	VI	Japan	Pseudo-electromagnetic retarding medium using loop coils, K. MORITA (E)
57	VI	Japan	A M-derived Waveguide filter, H. YANAI, J. HAMASAKI (E).
58	VI	Japan	A distributed coupled surface wave bandpass filter, Y. MORIWAKI, T. KAWAMURA (E).
59	VI	Japan	A broadband coaxial-to-waveguide junction, S. TANAKA (E).
60	VI	Japan	Current distribution on a rectangular plate and its effective area, K. MORITA, T. SEKIGUCHI (E).
61	VI	Japan	A new broadband antenna, S. OKAMURA, M. SUMITA (E).
62	VI	Japan	A wideband microwave antenna using circularly polarized waves, S. KAWAZU (E).
63	VI	Japan	A corrugated plane radiator, Y. MORIWAKI, T. KAWAMURA (E).
64	V	Czechoslovakia	About one possibility of using small-aperture antennas for estimating the position of local sources of radiowaves on the sun's disk, J. BUDEJICKY (E).
65	III	Czechoslovakia	Method of Ionospheric prediction, E. CHVOJKOVA (E).
66	III	Japan	A new possibility of long-distance propagation of metric waves, E. CHVOJKOVA.
67	III	Czechoslovakia	Refraction of radiowaves in an ionised medium, E. CHVOJKOVA (E).
68	VI	Czechoslovakia	Electromagnetic properties of a rotating plasma, E. CHVOJKOVA (E).
69	III	Czechoslovakia	Ionospheric layer during photo-ionisation, Theory of bifurcation and rocket research, E. CHVOJKOVA (E).

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70	III	Czechoslovakia	On the relation between the night E-layer above Lindau/Harz and the geomagnetic activity, A. HAJKOVA, J. MRAZEK (E).
71	III	Czechoslovakia	Measuring of the number of fadings, P. TRISKA (E).
72	III	Czechoslovakia	On the presence of a sporadic E-layer above Lindau-Harz during the period between 1948 and 1955, J. MRAZEK (E).
73	VI	Czechoslovakia	Second-harmonic signal generator with semiconductor diodes, J. KARPINSKY (E).
74	VI	Czechoslovakia	Contribution to the theory of the exponential step-lines, B. G. KAZANSKY (E).
75	VI	Czechoslovakia	Notes on transmission line equations in terms of normalized impedance and reflection coefficient, B. G. KAZANSKY (E).
76	VI	France	On the notion of infinitely thin and infinitely conducting screens, P. POINCELOT (*C. R. Académie des Sciences*, t. 243, n° 21, Nov. 1956, 1616-1618) (F).
77	III	Morocco	The nocturnal ionization of the E-region and the geomagnetic activity, A. HAUBERT (F).
78	III	Morocco	On large vertical motions in the F-region, observed in Casablanca, A. HAUBERT (F).
79	III	Morocco	The temperature gradients in the E and F1 regions, from ionospheric soundings in Casablanca, A. HAUBERT (F).
80	VI	Sweden	A new method for measuring phase and amplitude distribution of antenna currents, as applied to the reflection free antenna, E. CASSEL (E).
81	II	Czechoslovakia	Quasi-Rayleigh fading in tropospheric propagation, Ing. P. BECKMANN (E).

N°	Commission	Country	Titles and Authors
82	VI	Czechoslovakia	The reflection of electromagnetic waves from rough surface, Same author (E)
83	I	U.S.S.R.	Frequency (phase) multipliers for measuring devices, N. E. ZHABOTINSKY, U. L. SVERDLOV, Y. I. SVERCHKOV (E).
84	II	U.S.S.R.	Inhomogeneous path and general features of ground wave propagation, E. L. FEINBERG (E).
85	II	U.S.S.R.	Fluctuations in a wave scattered by inhomogeneities whose velocities are stationary random-functions of the time G. GORÉLIK, M. RODAK, A. FRANTZESSON (F).
86	II	U.S.S.R.	Theory of wave propagation in the turbulent atmosphere (Review of works carried out in the U.S.S.R.), V. A. KRASSILNIKOV (E).
87	II	U.S.S.R.	On the scattering theory of electromagnetic waves in the medium with random irregularities of refraction index, V. A. KRASSILNIKOV and V. V. MERKULOV (E).
88	III	U.S.S.R.	On the theory of propagation of radio waves in the ionosphère, V. L. GINZBURG (E).
89	III	U.S.S.R.	Scattering of radio waves in the ionosphere and long-range propagation of ultra-short waves, J. L. ALPERT (E).
90	III	U.S.S.R.	Analysis of the waveforms of atmospherics and the velocity of audio frequency electromagnetic waves, J. L. ALPERT, S. V. BORODINA (E).
91	III	U.S.S.R.	Investigation of the ionosphere layer of height irregular structures during simultaneous reception at different frequencies ; V. D. GUSSEV, S. F. MIRKOTAN (E).

N°	Commission	Country	Titles and Authors
92	III	U.S.S.R.	Investigation of ionospheric irregularities by means of measuring phase path variations of radio pulse reflected from the ionosphere, V. D. GUSSEV, L. A. DRATCHEV (E).
93	V	U.S.S.R.	On solar radio emission, V. V. VITKEVITCH (E).
94	V	U.S.S.R.	Research on the irregular structure of the ionosphere by means of radio astronomical methods, V. V. VITKEVITCH, J. L. KOKURIN (E).
95	V	U.S.S.R.	Observations of polarized sunspot radiation at a wavelength of 3 cm, D. V. KOROLKOV, N. S. SOBOLEVA (E).
96	VI	U.S.S.R.	Correlation theory of electric fluctuations and thermal radiation, S. M. RYTOV (E).
97	VI	U.S.S.R.	Phase-fluctuations in self-oscillators. Theories and measuring methods, G. GORELIK, G. IOLKINE (F).
98	VI	U.S.S.R.	Propagation of pulses in a strongly non linear system with delayed feedback, Y. NEIMARK, Y. MAKLAKOV, L. IOLKINE (F).
99	VI	U.S.S.R.	Frequency conversion by a reflex klystron, E. N. BAZAROV, M. E. ZHABOTINSKY (E).
100	VI	U.S.S.R.	Group velocity of attenuated waves, L. A. WAINSTEIN (E).
101	VI	U.S.S.R.	On the theory of the maser and fluctuations of its oscillations, V. S. TROITZKY (E).
102	VI	U.S.S.R.	Surface electromagnetic waves, M. A. MILLER, V. I. TALANOV (E).
103	VII	U.S.S.R.	Electron waves in periodic structure, L. A. WAINSTEIN (E).
104	III	Sweden	Preliminary results of an investigation of propagation conditions at very low frequencies, R. LINDQUIST (E).

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105	II	Poland	Comparison of Millington's method and equivalent numerical distance method with theory, Z. GODZINSKI (E).
106	VI	Poland	Remarks on statistical methods in communication theory, J. SEIDLER (E).
107	VI	Poland	Systematization of the influence of non linear factors on the L-C generator frequency, J. GROSZKOWSKI (F).
108	VI	Poland	Uniform realisation of operators by means of linear elements by R. KULIKOWSKI (E).
109	VI	Poland	Estimation methods in the theory of non-linear and parametric filters, same author (E).
110	VI	Poland	Pulse propagation in wave guides, GAJEWSKI (E).
111	II	U.S.A.	Comparison of measured and computed refractive bending in the troposphere, L. J. ANDERSON, L. G. TROLESE, J. B. SMYTH (E).
112	II	U.S.A.	Foreground terrain effects on overland microwave transmission, L. G. TROLESE (E).
113	VI	United Kingdom	Guided Waves, Prof. H. M. BARLOW (E).
114	II	—	Report of work of C.C.I.R. Study Group V at the VIIIth Plenary Assembly in Warsaw 1956, R. L. SMITH-ROSE, Chairman (E).
115	IV	India	Waveform studies of electric field-changes during cloud-to-cloud lightning discharges, B. A. P. TANTRY, R. S. SRIVASTAVA, S. K. KHASTGIR (E).
116	III	Germany	Lunar tidal variations of midday critical frequencies and lowest nighttime critical frequencies of the F2 layer at Slough and Lindau, G. LANGE-HESSE, E. SCHOTT (E).

N°	Commission	Country	Titles and Authors
117	II	Germany	Some remarks about scattering-experiments in the 100 Mc/s-band, Dr. J. GROSSKOPF (E).
118	VI	Italy	Analysis of d. c. networks including ideal rectifiers, G. BIORCI (E).
119	VI	Italy	Negative resistance two-ports considered as reactive elements governed by a voltage or a current, L. PIGLIONE (F).
120	II	Italy	Some results of propagation tests at 1000 Mc/s and 4000 Mc/s on two optical paths of different lengths, F. CARASSA, B. PERONI (E).
121	VI	United Kingdom	Operational calculus, Fourier transform or Laplace transform ? W. Proctor WILSON, G. G. MAYO, J. W. HEAD (E).
122	I	United Kingdom	Report on work carried out in Great Britain during the period 1954-1957, L. ESSEN (E).
123	II	United Kingdom	Report of the British National Committee on tropospheric wave propagation, R. L. SMITH-ROSE (E).
124	III	United Kingdom	Report of the British National Comtee to Commission III, W. J. G. BEYNON (E).
125	IV	United Kingdom	Report of the British National Committee to Commission IV, F. HORNER (E).
126	IV	United Kingdom	Atmospheric Radio noise at frequencies between 10 kc/s and 30 kc/s, J. HARWOOD (E).
127	IV	United Kingdom	The relation between atmospheric radio noise and lightning, F. HORNER (E).
128	V	United Kingdom	Report on British work in radio astronomy since 1954, A. C. B. LOVELL (E).
129	VI	United Kingdom	National Progress Report : Commission VI, W. Proctor WILSON, J. W. HEAD, G. D. MONTEATH, H. M. BARLOW (E).

N°	Commission	Country	Titles and Authors
130	VI	United Kingdom	Surface wave research at University College London, J. BROWN (E).
131	VI	United Kingdom	The application of diffraction theory to aerial measurement problems, J. BROWN (E).
132	VI	United Kingdom	Survey paper on guided waves, H. M. BARLOW (E).
133	VI	United Kingdom	An approximated realisation of « Quadrature », G. G. GOURIET, G. F. NEWELL (E).
134	VI	United Kingdom	The negative entropy of recorded informations, D. A. BELL (E).
135	VI	United Kingdom	Propagation characteristics of low-loss tubular metal wave-guides, H. M. BARLOW (E).
136	VI	United Kingdom	A note on the definition of groupe delay, G. G. GOURIET (E).
137	VI	United Kingdom	A method for calculating the horizontal radiation patterns of dipole arrays around support masts of intermediate size, P. KNIGHT (E).
138	VII	United Kingdom	Report of the National Committee to Commission VII, C. W. OATLEY (E).
139	I	Switzerland	Report of the National Committee to Commission I, Prof. KONIG (E) (F).
140	II	Switzerland	Report of the National Committee to Commission II, Dr. GERBER (E) (F).
141	IV	Switzerland	Report of the National Committee to Commission IV, Prof. J. LUGEON (E) (F).
142	V	Switzerland	Report of the National Committee to Commission V, Prof. WALDMEIER (E) (F).
143	VI	Switzerland	Report of the National Committee to Commission VI, Prof. BALDINGER (E) (F).
144	VII	Switzerland	Report of the National Committee to Commission VII, Prof. SCHAETTI (E) (F).
145	III	Switzerland	Report of the Chairman of Sub-Commission III*b* (F).

N°	Commission	Country	Titles and Authors
146	VII	U.S.A.	Oscillation phenomena in gas discharges, W. P. ALLIS (E).
147	VII	U.S.A.	The physics of the cathodes, L. S. NEEGARD (E).
148	VII	U.S.A.	The physics of semiconductor devices for radio application, W. SHOCKLEY (E).
149	VII	U.S.A.	The source and nature of noise in electron beams, J. R. PIERCE (E).
150	VI		Survey of Circuit Theory, Report of Sub-Commission VI.2, Prof. B. D. H. TELLEGEN (E).
151	IV	United Kingdom	The use of magnetic tape recording for studying atmospheric noise structure, C. CLARKE (E).
152	II	United Kingdom	Some experimental investigations of long-range VHF and UHF tropospheric propagation, J. A. SAXTON, G. W. LUSCOMBE (E).
153	II	United Kingdom	Some features of VHF and UHF ground-wave propagation, J. A. SAXTON, B. N. HARDEN (E).
154	VI	France	Draft of an U.R.S.I. monography-Information theory of a complete communication system, J. LOEB (F).
155	II	—	Report on Radio Wave Propagation within the horizon (E).
156	I	New Zealand	Report of the National Committee to Commission I (E).
157	II	New Zealand	Report of the National Committee to Commission II (E).
158	III	New Zealand	Report of the National Committee to Commission III (E).
159	IV	New Zealand	Report of the National Committee to Commission IV (E).
160	II	Italy	Report of the National Committee to Commission II (E).
161	III	Italy	Report of the National Committee to Commission III (E).
162	V	Italy	Report of the National Committee to Commission V (E).

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163	VI	Italy	Report of the National Committee to Commission VI (E).
164	VII	Italy	Report of the National Committee to Commission VII (E).
165	I	Netherlands	Report of the National Committee to Commission I (E).
166	II	Netherlands	Report of the National Committee to Commission II (E).
167	III	Netherlands	Report of the National Committee to Commission III (E).
168	V	Netherlands	Report of the National Committee to Commission V (E).
169	III	Morocco	Report of the National Committee to Commission III (F).
170	IV	Morocco	Report of the National Committee to Commission IV (F).
171	II	Czechoslovakia	Report of the National Committee to Commission II (E).
172	III	Czechoslovakia	Report of the National Committee to Commission III (E).
173	V	Czechoslovakia	Report of the National Committee to Commission V (E).
174	II	Sweden	The influence of moisture in the ground temperature and terrain on ground wave propagation in the VHF-Band, B. JOSEPHSON, A. BLOMQUIST (E).
175	II	Sweden	Some microwave propagation experiments from a « just-below-horizon » path, B. JOSEPHSON, F. EKLUND (E).
176	II	Sweden	Distance dependence, fading characteristics and pulse distorsion of 3000 Mc/s trans-horizon signals, B. JOSEPHSON, G. CARLSON (E).
177	III-V	Sweden	On the origin of radar echoes associated with auroral activities, J. MEOS, S. OLVING (E).
178	V	Sweden	Observations of radio star scintillation at high latitudes, H. HVATUM, T. ORHAUG (E).
179	V	Sweden	Continued visual and radar observations of meteor, B. A. LINDBLAD (E).

N°	Com-mission	Country	Titles and Authors
180	VII	Sweden	On the space charge wave-length of perpendicularly inhomogeneous electron stream, O. E. H. RYDBECK (E).
181	VII	Sweden	An experimental investigation of space charge waves in a finite velocity gap, O. STEINSTÖ (E).
182	VII	Sweden	Space charge waves in an electron beam with variable velocity, S. OLVING (E).
183	VII	Sweden	Representation of the complexe propagation constants of a travelling wave tube on a Smith diagram, S. OLVING (E).
184	I	Canada	Report of the National Committee to Commission I (E).
185	II	Canada	Report of the National Committee to Commission II (E).
186	III	Canada	Report of the National Committee to Commission III (E).
187	V	Canada	Report of the National Committee to Commission V (E).
188	VI	Canada	Report of the National Committee to Commission VI (E).
189	VII	Canada	Report of the National Committee ot Commission VII (E).
190	I	Germany	Report of the National Committee to Commission I (E).
191	II	Germany	Report of the National Committee to Commission II (E).
192	III	Germany	Report of the National Committee to Commission III, W. DIEMINGER (E).
193	IV	Germany	Report of the National Committee to Commission IV, A. EHMERT (E).
194	V	Germany	Report on German Work in Radio Astronomy 1954-1955 (E).
195	VI	Germany	Report of the National Committee to Commission VI (E).
196	VII	Germany	Report of the National Committee to Commission VII (E).
197	I	Japan	Report of National Committee to the Commission I, I. KOGA (E).

N°	Commission	Country	Titles and authors
198	II	Germany	Report of the National Committee to Commission II, H. HATAKEYAMA, K. ISONO (E).
199	III	Japan	Report of the National Committee to Commission III, S. NAMBA (E).
200	IV	Japan	Report of the National Committee to Commission IV, A. KIMPARA (E).
201	V	Japan	Report of the National Committee to Commission V, Y. HAGIHARA (E).
202	VI	Japan	Report of the National Committee to Commission VI, K. MORITA (E).
203	VII	Japan	Report of the National Committee to Commission VII, M. KOTANI, T. OKABE, Y. MUTO, G. M. HATOYAMA, Y. KOIKE, Y. ASAMI (E).
204	I	Poland	Report of the National Committee to Commission I (E).
205	II	Poland	Report of the National Committee to Commission II (E).
206	III	Poland	Report of the National Committee to Commission III (E).
207	VI	Poland	Report of the National Committee to Commission VI (E).
208	VII	Poland	Report of the National Committee to Commission VII (E).
209	I	France	Report of the National Committee to Commission I (F).
210	II	France	Report of the National Committee to Commission II (F).
211	IV	France	Report of the National Committee to Commission IV (F).
212	VI	France	Report of the National Committee to Commission VI (F).
213	I	Sweden	Report of the National Committee to Commission I, H. BJÖRKLUND (E).
214	II	Sweden	Report of the National Committee to Commission II, K. FEHRM (E).
215	III	Sweden	Report of the National Committee to Commission III, S. GEJER (E).
216	IV	Sweden	Report of the National Committee to Commission IV, H. NORINDER (E).
217	V	Sweden	Report of the National Committee to Commission V, O.E.H. RYDBECK (E).

N°	Commission	Country	Titles and Authors
218	VI	Sweden	Report of the National Committee to Commission VI, E. HALLÉN (E).
219	VII	Sweden	Report of the National Committee to Commission VII, H. WALLMAN (E).
220	III	France	Report of the National Committee to Commission III (F).
221	VI	France	Junction converting rectangular TE_{01} waves into circular TE_{01} waves, M. P. MARIÉ (F).
222	I	Australia	Report of the National Committee to Commission I (E).
223	III	Australia	Report of the National Committee to Commission III (E).
224	IV	Australia	Report of the National Committee to Commission IV (E).
225	V	Australia	Report of the National Committee to Commission V (E).
226	VI	France	Lens focalizing circularly polarized waves into a given mode, M. P. MARIÉ (F).
227	VII	Netherlands	Report of the National Committee to Commission VII (E).
228	III	Japan	Report of Commission IIIc of the Japanese National Committee, I. KOGA (E).
229	IV	Sweden	Variation forms and time sequence of multiple lightning strokes, H. NORINDER, B. VOLLMER (E).
230	IV	Sweden	Pre-discharges in relation to subsequent lightning strokes, H. NORINDER, E. KNUDSEN (E).
231	IV	Sweden	Atmospheric electric discharges from distant snow squalls and occlusion front same authors (E).
232	II	Poland	Some results of tropospheric scatter propagation measurements in Poland, S. MANIZARSKI, J. MOLSKI, L. KIERNOZYCKI (E).
233	VI	Netherlands	Report of the National Committee to Commission VI (E).

N°	Commission	Country	Titles and Authors
234	VI	Netherlands	On codes for error-correction and for automatic repetition systems, F. L. H. M. Stumpers (E).
235	III-V-VI	Sweden	Electromagnetic wave reflection and space charge wave propagation in electron stream, O. E. H. Rydbeck (E).
236	I	—	Recommendations of the International Committee on Weights and Measurements to Commission I (F).
237	V	France	Report of the National Committee to Commission V (F).
238	VII	France	Report of the National Committee to Commission VII (F).
239	IV	U.S.A.	Lightning discharge channel characteristics and related atmospherics radio interference, M. M. Newman (E).
240	IV	Poland	Report of the National Committee to Commission IV (E).
241	I	United Kingdom	Power measurements by film bolometers in rectangular waveguides, L. A. Lane (E).
242	I	U.S.A.	Report of the National Committee to Commission I (E).
243	II	U.S.A.	Meteorological studies of refractive index distributions, K. H. Jehn, V. E. Moyer, J. R. Gerhardt, N. K. Wagner (E).
244	II	U.S.A.	Radio propagation measurements at millimeter wavelengths, H. G. Booker, W. E. Gordon (E).
245	II	U.S.A.	The role of stratospheric scattering in radio communication, H. G. Booker, W. E. Gordon (E).
246	II	U.S.A.	On the total bending of radio waves, B. R. Bean, B. A. Cahoon (E).
247	II	U.S.A.	On the prediction of VHF transmission loss from the surface refractivity index, B. R. Bean (E).

N°	Commission	Country	Titles and Authors
248	II	U.S.A.	Dependence of VHF-UHF radio transmission loss on angular distance, P. L. RICE (E).
249	II	U.S.A.	Overwater scatter propagation in thunderstorm conditions, W. S. AMENT, F. C. MACDONALD, D. L. RINGWALT (E).
250	II	U.S.A.	Meter wavelength propagation at great distances and heights beyond the radio horizon, L. A. AMES, E. J. MARTIN, T. F. ROGERS (E).
251	III	Italy	Further experiments on the non-linear effects in the ionosphere, M. CUTOLO (E).
252	III	Italy	Remarks on the theories of self demodulation of radiowaves in the ionosphere, M. CUTOLO (E).
253	III	Italy	Correlation between E-layer and the 500 MB surface position of gyro-interaction, M. CUTOLO, A. NAPOLETANO (E).
254	IV	—	Report of a Sub-Commission (E).
255	I	U.S.A.	A fade-cancelling zero beat indicator, R. J. BLUME (E).
256	I	U.S.A.	Low frequency standards transmission, W. D. GEORGE (E).
257	I	U.S.A.	Accuracy of WWV and WWVH, W. C. STIEKLER (E).
258	I	U.S.A.	Status report on microcalorimetric technique, G. F. ENGEN (E).
259	V	U.S.A.	Instrumentation techniques in radio-astronomy, P. D. STRUM (E).
260	V	U.S.A.	An X-band switched comparison radiometer, H. I. EWEN (E).
261	VI	U.S.A.	National Committee Report to Sub-Commission VI.3 (E).
262	VI	—	Report of Sub-Commission VI. 3(E).
263	III	U.S.A.	Drift motions of auroral ionization, B. NICHOLS (E).
264	V	U.S.A.	The fading of meteoric radio echoes, A. MANNING (E).

N°	Commission	Country	Titles and Authors
265	V		X-band observations of radio stars and planets, F. DRAKE (E).
266	V	U.S.A.	Oblique meteoric echoes from overdense trails, A. MANNING (E).
267	IV	Sweden	Results obtained recently regarding the mechanism of lightning discharges, H. NORINDER (E).
268	II	U.S.A.	Observations of antenna beam distorsion in trans-horizon propagation, Alan T. WATERMAN (E).
269	II	U.S.A.	Some general relationships in trans-horizon propagation, same author (E).
270	II	U.S.A.	Radio studies of atmospheric turbulence on line of sight paths, I. W. HERBSTREIT, M. C. THOMSON Jr. (E).
271	VI	U.S.S.R.	Method of electronic phototelegraphy with high efficience of information transmission, V. A. ILYIN (E).
272	VI	U.S.A.	Electrodynamics of material bodies, L. J. CHU (E).
273	VI	U.S.S.R.	On the capacity of channels with random parameter fluctuations, V. I. SIFOROV (E).
274	III	France	Magneto-ionic theory and E-region Triple forked traces, D. LÉPÉCHINSKY (F).
275	III	France	Propagation of a plane electromagnetic wave through an ionized layer of finite thickness in the presence of collisions, P. POINCELOT, L. ROBIN (F).
276	VI	U.S.A.	Far field scattering from bodies of revolution, K. M. SIEGEL (E).
277	VI	U.S.A.	An anti-multipaths communication system (Rocke), R. PRICE, P. E. GREEN Jr. (E).
278		U.S.A.	Notes on the difference between one-dimensional time filters (Networks) two-dimensional space filters (Optics), and three (or more) dimensional space-time filters (Antenna), F. J. ZUCKER (E).

N°	Commission	Country	Titles and Authors
279	III	U.S.A.	The third magneto-ionic reflection level, J. W. WRIGHT (E).
280	III	U.S.A.	Various types of low frequency reflection in the ionosphere, H. POVERLEIN (E).
281	III	France	Measurement of ionospheric winds, P. LEJAY (F).
282	III	U.S.A.	Solar ionizing radiation effective in lower ionosphere, H. FRIEDMAN, T. A. CHUBB, J. E. KUPPERIAN Jr. (E).
283	III	U.S.A.	Ionospheric storm analysis from «*f*-plots », A. H. SHAPLEY (E).
284	III	U.S.A.	The morphology of ionospheric storms, M. SUGIURA, R. NORTON (E).
285	III	U.S.A.	Mode identification, MUF and wave angles in long distance high frequency propagation, R. SILBERSTEIN (E).
286	III	U.S.A.	VLF ionospheric propagation, J. R. WAIT (E).
287	III	U.S.A.	World-wide observations of short waves fadeouts, J. V. LINCOLN (E).
288	III	U.S.A.	Ionospheric electron densities and differential absorption, J. C. SEDDON, J. E. JACKSON (E).
289	III	U.S.A.	Ionospheric soundings at low frequencies, J. M. WATTS (E).
290	III	U.S.A.	Ionospheric effects of the great solar outburst of February 23, 1956, R. W. KNECHT (E).
291	III	U.S.A.	The thermal and gravitational excitation of atmospheric currents, M. C. WHITE (E).
292	IV	U.S.A.	Whistlers and associated phenomena, R. A. HELLIWELL (E).
293	V	U.S.A.	On the directional properties of meteor burst propagation, V. H. ESHLEMAN, R. F. MLODNOSKY (E).
294	V	U.S.A.	Radar studies of the 15th magnitude meteors, P. B. GALLAGHER, V. R. ESHLEMAN (E).

N°	Commission	Country	Titles and Authors
295	V	U.S.A.	The initial radius of meteoric ionization trails, A. MANNING (E).
296	II	U.S.A.	Report of U.S.A. Commission II (E).
297	III	U.S.A.	Report of U.S.A. Commission III (E).
298	IV	U.S.A.	Report of U.S.A. Commission IV (E).
299	V	U.S.A.	Report of U.S.A. Commission V (E).
300	VI	U.S.A.	Report of U.S.A. Commission VI (E).
301	VI	U.S.A.	A multiplication theorem for positive real functions, F. REZA (E).
302	II	U.S.A.	Theoretical results on tropospheric research on propagation in U.S.A., 1954-1957, H. STARAS, A. D. WHEELON (E).
303	III	U.S.A.	A fading origin experiment for radio waves reflected from the ionosphere, T. N. GAUTIER, R. S. LAWRENCE, W. F. UTILANDI, B. WIEDER (E).
304	VII	U.S.A.	Report of U.S.A. Commission VII (E).
305	III	France	Influences of the absorption on the ionospheric reflection coefficient, P. POINCELOT (F).
306	III-V	—	Report of the Chairman of the Permanent Committee on Ursigrams (F).
307	VI	Canada	Scattering from a circular loop, V. H. WESTON (E).
308	VI	Canada	Vector wave functions in toroidal coordinates, V. H. WESTON (E).
309	III	France	On the reflection coefficient of the ionospheric layers, Geneviève PILLET (F).
310	V	—	Report of Sub-Commission Vc (E).
311	VI	U.S.A.	Far field scattering from bodies of revolution, K. M. SIEGEL (E).

Plenary Closing Session

The meeting was called to order by Rev. Father Lejay at 9 a. m. Eng. E. Herbays, Secretary General, was invited to read the resolutions and recommendations submitted by the Executive Committee (see p. 68).

These proposals were unanimously adopted.

The President asked Dr. L. V. Berkner, new elected President, to take place at his side.

Then all the Commission Chairmen successively took the floor to give a summary of the work of the Commissions during the meeting, and to submit to the approval of the General Assembly the resolutions and recommendations drafted by the Commissions.

The reports, published in Parts 1 to 7 of the Proceedings, are accepted and the recommendations and resolutions (see pp. 72) are unanimously adopted.

The President invited then the Chairmen of Special Committees to read their reports.

The following took the floor :

Sir Edward V. Appleton, Chairman of the U.R.S.I./A.G.I. Committee (see p. 127).

Dr. J. H. Dellinger, Chairman of the Committee on U.R.S.I.-C.C.I.R. Cooperation (see p. 63).

Dr. Metzler, Director of C.C.I.R., who expressed his thanks for the welcome he met at this General Assembly, stressed the importance for the telecommunications of the co-operation between C.C.I.R. and U.R.S.I. He expressed his satisfaction at the relationship between both organizations, and wished that the topics submitted by C.C.I.R. to U.R.S.I. be dealt with as soon as possible.

Dr. J. H. Dellinger, Chairman of the Publication Committee (see p. 65).

Prof. B. D. H. Tellegen, Chairman of the Finance Committee (see p. 95).

The President expressed his gratitude to the speakers, and the reports were unanimously accepted.

Closing Speech of Father P. Lejay,

Retiring President

My dear Colleagues,

The reports from the Commissions which we have just heard have shown the vitaliy of U.R.S.I. I think I should only be expressing the unanimous opinion by saying that our XIIth General Assembly knew fresh progress and that it has displayed an activity hitherto unknown. Our old-established Commissons have found a number of new subjects for research to examine and discuss and our more recently established Commissions have made an enthusiastic start towards new scientific conquests.

The organisation of our Assembly has also certainly made great progress. Although, in such a short time, it is not easy for everyone to study the numerous problems which are of interest to all, nor to make all the desired contacts with colleagues of other nationalities, nor to leave free all the time that would be necessary for fruitful discussions, nevertheless I believe that this aim, which is one of the essential goals of this Union, has been achieved as completely as possible.

Before closing this General Assembly I would like to examine the reasons for its success.

First of all this success is due to the work, often of considerable volume, which has been done before the Assembly by the Presidents of the Commissions. They have been able to guide the discussions towards the subjects of the most general interest and to promote most interesting interventions with great dexterity and authority. The new rulings concerning the management of the sessions, which were unanimouly approved, have proved most effective, thanks to the zeal shown by the Presidents for nearly two years and we must express our gratitude to them for the admirable manner in which they have played their part.

During the actual Assembly the Secretaries of the Commissions have shown the same ardour. Already a large number of reports have been drawn up, representing a vast amount of work. The role of the Secretaries is very important because it depends on them to assure that the reports of the sessions are as fruitful as we expect. We must not forget all the trouble they have taken to provide the intellectual benefit which we have obtained.

Another reason for the success of this Assembly, and not the least, is, as you will doubtless agree, the devotion of our Secretary General. On this subject I take the liberty of expressing my personal appreciation.

For five years I have been associated with his activity. Colonel Herbays has been the originator of many enterprises that have transformed our Assemblies. He has never spared himself and I am happy to have the occasion here to pay him friendly homage. During the numerous visits he has made to Paris, and he has come each time that an important question has arisen that could not be resolved by correspondence, I have been able to appreciate his devotion to the interests of U.R.S.I. as well as the quality of his initiative and his international understanding. We owe him much. The constant progress of our meetings, despite the increasing difficulties that have had to be overcome owing to the growth of our activities, has been greatly due to him. Before leaving the Presidency of the Union, I am happy to have this opportunity to tell him, not without a certain emotion, that I shall always remember his friendly collaboration.

Nor shall I quickly forget the cooperation that has existed with the Officers of the Board on the many occasions during the years that have led up to Boulder, with the Vice-Presidents, Dr. Berkner, Dr. Burrows, Dr. Smith-Rose and Professor Tellegen and many other eminent men amongst whom I would mention our former President, Sir Edward Appleton, Professor van de Pol and all those whose wisdom has inspired so many happy decisions. The efficacy of the steps taken on their advice is clearly shown to-day.

But all this preparatory work would have been fruitless if it had not been continued here at Boulder. This was the work of an admirable organising committee, a local organisation which we have greatly appreciated and which was arranged by Mr. Norton and Mr. Shapley. Dr. Gordon and Dr. Wells were responsible for the outside organisation which provided for the welcome of so many foreign personalities. We must not forget the staff of the National Bureau of Standards who were in charge of the material organisation and, above all, President Dellinger who, assisted by his aimiable secretary Mrs MacIntyre, has coordinated and arranged everything, thanks to his incomparable savoir faire inspite of difficulties of every sort and kind. How can we ever

forget the beautiful excursions and the magnificent panoramas, the visits to so many laboratories and observatories that were all so well organised and so full of interest.

But, alas, I must not linger on these subjects. It is time for me to present my successor to you. The Executive Committee proposes Dr. Berkner as President of U.R.S.I.

It is not possible for me to announce all his titles, from among his numerous occupations I must choose those that will best show his special competence to direct our Union. Dr. Berkner is a technicien in Radioelectricity. He has spent many years with the National Bureau of Standards and in the department of Terrestial Magnetism at the Carnegie Institute. It was there, as you will remember, that he took a special interest in the study of the Ionosphere, in the F1 region and in the behaviour of the ionised layers during magnetic storms. All of you are aware of his work at the Huancayo station.

Dr. Berkner has served in the Navy and took part in the first Byrd expedition. He has also served in the Air Service where he first brought his knowledge of radar and electronics to the requirements of the armed forces and later the application of tropospheric diffusion.

On these technical bases a brilliant career was founded : promoted to admiral in the American Naval Reserve, Dr. Berkner took an active part in the organisation of the Research and Development Board and later in the Joint Military Assistance Coordinating Committee of National Defence.

Finally, but I must leave out a great deal, as President of Associated Universities, he is to-day making a large contribution to the scientific education of American youth.

All these titles and the numerous honours that he has received and which it is impossible for me to enumerate here, prove his qualities as a technicien, his fertile imagination, the scope of his knowledge and his administrative ability.

Dr. Berkner has already rendered valuable service to our Union and to other international organisations. Furthermore the International Council of Scientific Unions has entrusted him with the Presidence of the most eminent international scientific organisation. In appointing him President of U.R.S.I. our Union is assured that Dr. Berkner will devote all his qualities to the service of inter-

national science with that great spirit of cooperation that is his, for the greater profit and advancement of science. He will contribute largely to the development of the friendly spirit that has always existed in U.R.S.I. and he will certainly give it fresh life. I am very happy to hand over to him the trust which you confided to me. And now, whilst thanking you once more and for the last time for all the help you have given me in my task, I ask Dr. Berkner to take his seat in the presidential chair.

Address of Acceptance by the Incoming President

Mr. President, Members of U.R.S.I.,

No one can assume the leadership of a really great organization without a feeling of humbleness, and the U.R.S.I. is great. It has become great for many reasons.

First, we live in great times — times to which the U.R.S.I. and its members have made a substantial and even major contribution. For the first time in civilized history, man has occupied the heretofore unknown Seventh Continent, the Antarctic, on a massive scale. This occupation is made possible by the communications in which U.R.S.I. has played such an important part in creating and organizing. The occupation of the Antarctic is marked by the research in radio wave propagation and the physics of the outer atmosphere in which our commissions have played a dominate role. The Arctic is now almost continuously occupied by large numbers of people, this was made possible by the communication systems particularly devised by members of U.R.S.I. to provide reliable inter-communication in this region of aurorae and geomagnetic storms. Our members are in remote stations and on ice floes to make observations that are vital to the advance of our science. In the exploration of the atmosphere with rockets, we have heard at this assembly of the great advances in man's knowledge. Plans are now nearing completion for the scanning of the whole earth by instrumented satellites for study of phenomena that are critical to science. Our members are playing a major part in these launchings. In its whole leadership of the I.G.Y., U.R.S.I. has been in the vanguard in the exploration of

our planet and our universe. The knowledge that we are now acquiring insures for U.R.S.I. its continued activity in the very forefront of science.

Second, U.R.S.I. is great because the subject with which it deals is at the very heart of science. Radio and electronics provide the nerve sytsems for scientific observations in essentially every field of science in our day. The excitement of scientific advance reported and discussed at this Assembly illustrates the vitality of our interests. Instruments of our making put men in close contact whatever may be their physical separation over the globe. New forms of observation such as very high frequency scatter have been developed by U.R.S.I. scientists and have greatly extended man's power to communicate. The study of whistlers reported at this Assembly with their association of the dawn chorus has extended our power of observation into the exosphere and has disclosed the extraordinary phenomena of nature's traveling wave-tube amplifier with the sun as the cathode and with the earth's magnetic field providing the focussing elements. The sun, its corona, its great eruptions and hot spots, and its physics ties us directly into the physical processes that produce a wide range of terrestrial phenomena. And in the past few years we have extended our interest to space through radio astronomy, to the galaxies, and now to external galactic and extra-galactic groups. This new science, developed under the direct encouragement of the U.R.S.I., now promises in some respects to pass the power of visual astronomy, and certainly to supplement visual astronomy very strongly in our understanding of the astrophysical and cosmological processes of the universe. We are reminded here of the prescience of Sir Edward Appleton in his presidential lecture before the British Association a few years ago when he was able to foresee the progress that is now becoming a reality in the field of radio astronomy.

The power of our techniques is ever expanding, and we have heard at this meeting of the « mazor », that remarkable low noise amplifier that will inevitably increase our power of detection and observation of phenomena in the micro-wave region. U.R.S.I. has assumed leadership in the field of standardization of apparatus and nomenclature that has given reality and universality to the instruments that we devise for use in all of the scientific disciplines.

U.R.S.I. deals with simple particles, electrons and protons, but it deals with our most powerful and complex manifestations.

Third, U.R.S.I. is great because of the strength of its organization. This strength is derived from the national support given by the academies and councils of our adhering countries. It is derived from the great national committees of those countries, committees that are strong in their own right from the support of the scientists of their nations. U.R.S.I. derives strength from its commissions and sub-commissions and special committees and especially from the chairmen and leaders of these groups. The outstanding work of such committees as our Committee on the I.G.Y., the C.C.I.R., and World Wide Sounding Committee over the past three years illustrates the effective procedures of U.R.S.I. in providing world leadership and world standards. U.R.S.I. is strong because it has the machinery to deal with the scientific problems that confront it.

Fourth, U.R.S.I. is great because of its virility and its ability to evolve with the growth of its science. At this Assembly we have heard discussed new plans for more extensive symposia. We have learned to publish these symposia in the most effective form. I need only remind you of the popular volume prepared under the editorship of Dr. Beynon on « The Effect of Solar Eclipses on the Ionosphere » that appeared during the last triennium. This provides a standard of excellence for this new activity. Because of the strength of U.R.S.I. it has been possible at this meeting to propose a new scale of adherence which will continue to insure the financial support that is necessary for the continued effective operation of our great organization.

Fifth, U.R.S.I. is strong because it has been the forum that has brought together men of great intellectual capacity. Here men of East and West have joined in the common fellowship of the integrity of science. At the end of the month men of many nations will join together to confer on the scientific and peaceful uses of rockets and satellites. Out of relationships such as these have been derived the ideas that have stimulated our scientists and our laboratories everywhere into new discoveries and new developments that are of great benefit to both science and to man generally.

Finally, and above all, U.R.S.I. is strong because of the strength

and vision of its leaders throughout the history of U.R.S.I.'s growth. Among the early presidents appear the leading names in radio science. Our honorary presidents are men of great skill, ability, and intellectual strength who have given of themselves devotedly in the support of our scientific objectives. It is hardly necessary for me to name Sir Edward Appleton, Balth. van der Pol, and J. H. Dellinger. Our retiring president has devoted his major energy to the U.R.S.I. We all owe to Father Lejay a debt of gratitude for his leadership that we will find it difficult to repay. Each of these men have studied the U.R.S.I.with respect to the scientific stiuation of their time to grasp and to encourage its scientific opportunity. These men have given U.R.S.I. its virility.

So, U.R.S.I. is strong for many reasons — for its ability to capture the spirit of our times, for its place at the center of the nerve system of science, for its effective and virile organization, for the forum that it provides to its members, and for the quality of its leadership.

But by definition progress cannot stop. Even at this Assembly we have found new problems to be solved and new methods to be used. Our members have had vigorous discussions concerning the character of fluid flow in the atmosphere and are planning to join together to make extensive studies that can solve these most difficult physical and mathematical problems. Perhaps in a transient sense they will create a university in the reality of its ancient meaning, and the U.R.S.I. stands ready to provide the support and the organizational mechanism that can make these studies possible. This is but a single example of the ever-evolving requirements that our organization must meet.

The future challenges us with ever new instruments, new means of questioning science concerning her secrets, and new ideas that can simplify our interpretation and comprehension of what we observe. U.R.S.I. can provide the opportunity to join in friendly fellowship that can given these elements of science their greatest meaning.

Report of U.R.S.I. Committee on C.C.I.R. Work

This Committee was appointed by the 1954 General Assembly to assist the General Secretary in handling C.C.I.R. matters and to coordinate the work on C.C.I.R. topics in the U.R.S.I. Com-

missions. Its personnel comprises Dr. J. H. Dellinger (Chairman), Mr. B. Decaux, Dr. R. L. Smith-Rose, Dr. B. van der Pol. After the 1954 General Assembly it secured the responses by the Commissions on all C.C.I.R. topics referred by the 1953 (London) Plenary Assembly of the C.C.I.R., put them in coordinated form, and forwarded them, in English and French texts, to the General Secretary for official transmission to the C.C.I.R.

When the 1956 (Warsaw) Plenary Assembly of the C.C.I.R. referred to the U.R.S.I. some 28 topics (Recommendations, Resolutions, Reports, Questions, Study Programs), the Committee arranged with the General Secretary to publish them in the Information Bulletin (No. 100, Nov.-Dec. 1956, pp. 48-81), with a note calling attention to the desirability of careful and early study by the U.R.S.I.

The Committee also called the attention of the six Commission Chairmen concerned, to the importance of organizing work to insure U.R.S.I. responses to these topics, in March 1957 and again during the present General Assembly. The Commissions have in general found the topics of interest and have in all cases recognized the opportunity for useful application, through this means, of the results of U.R.S.I. studies. In a few cases specific responses are already available through the Commission studies, in others work on responses is assigned to working groups, and in still others the Commissions have adopted recommendations to encourage intensified work on the topics or related researches with a view to aiding future C.C.I.R. work.

Except for the last of these categories, each Commission Chairman is requested to submit the text of his Commission's response on each topic to the Chairman of this Committee as soon as possible and in any event not later than February 1 of next year, for the following reason. It is expected that the C.C.I.R. Study Groups concerned will hold meetings in August of next year, to do the principal work of preparation for the next Plenary Assembly of C.C.I.R. (to take place in April, 1959). The proposals for the Study Group meetings must be submitted four months in advance, i.e., by April 1, 1958. The period between February 1 and April 1 is a minimum period for correspondence regarding the U.R.S.I. responses in the pertinent Study Groups of the C.C.I.R.

Report of Publication Committee

1. — Proceedings of General Assembly

The mode of publication of the Proceedings of the 1954 General Assembly is considered a satisfactory model.

The distribution of copies to National Committees recommended in this Committee's 1950 Report has been followed and is considered satisfactory. A procedure for expediting the distribution analogous to that proposed in Sec. 2 for the Information Bulletin is recommended.

It is important that Commisson Chairmen and the Secretary General submit their reports, etc., promptly after the close of the General Assembly. The Commission Chairmen should serve as Associate Editors for their respective parts of the Proceedings, the Secretary General to be coordinator and General Editor.

2. — Information Bulletin

We are pleased to report that the U.R.S.I. is the only one of the Scientific Unions whose Bulletin is still being subsidized by Unesco, it being the only one that does an effective job of keeping its members informed of the various activities of the Union, its National Committees, and related matters of interest. To insure the continuation of the subsidy it is important that the Associate Editors, appointed one from each country, be active in submitting material (in the categories listed in our 1954 Report, Sec. 6).

The information submitted on technical meetings of National Committees should include a list of the papers presented at each such meeting.

To reduce delays in distribution of the Information Bulletin, the Secretary General is prepared to mail copies directly to the individual recipients instead of sending to the National Committee secretaries for distribution. All National Committees which wish to take advantage of this plan should send the list of individual recipients to the Secretary General.

3. — Special Reports

It is to be noted that the new scale of membership categories and subscription units increase the maximum number of « free »

copies of the Information Bulletin and General Assembly Proceedings to which each category other than 1 and 2 is entitled.

This is equitable, as the maximum number of « free » copies remains proportional to the cash contribution.

Only five Special Reports have been issued. These are particularly fine product of U.R.S.I.'s work and are worthy of such more activity. Future ones can be published and distributed, in some cases, by U.R.S.I. itself as in the past. In other cases, particularly when the special report is actually a book (by one or more authors), commercial publication will be more appropriate, along the line planned for the documentation of symposia (Sec. 4).

For each Special Report, one editor should be appointed by the Board of Officers.

4. — Symposium Documentation

As U.R.S.I. moves more fully into the holding of symposia, careful attention should be given to determining the form and method of publication of their results. A good example is the report of the eclipse symposium by Dr. Beynon. The forthcoming symposium on radio astronomy offers an opportunity to develop publication plans further.

It is important that for every symposium an Editing Committee be appointed, to assure that responsibility for proper publication be met. This can be appointed by the Organizing Committee.

The report or other material resulting from a symposium should be published commercially. Only one copy per subscription unit should be furnished free to each National Committee.

5. — Miscellaneous Publications

These include such things as the list of ionosphere stations, list of atmospheric radio noise measurement stations, history of U.R.S.I., and possibly I.G.Y. material. The 1954 recommendation that the I.G.Y. publication work be left essentially to the I.G.Y. organizations is reaffirmed. The 1954 request that the Secretary General be given active assistance on the U.R.S.I. history, by all concerned, is reaffirmed.

The Board of Officers should appoint an Editor for each miscellaneous publication, except where the work of preparation is minor and no burden on the Secretary General.

As in the case of symposium reports, only one copy per subscription unit should be furnished free to each National Committee.

6. — General

It becomes more difficult to obtain Unesco funds for publications. Unesco expects Unions which receive grants through I.C.S.U. to provide sums equal to the amounts of the grants. For the years 1954, 1955, 1956, the average Unesco grant per year has been $ 5608, and the amount provided from the U.R.S.I. treasury and sales $ 2214.

Publication needs and costs are certain to increase. In anticipation of continuing to receive a Unesco grant of $ 5608, it is therefore necessary that U.R.S.I. provide $ 3394 more per year for publications than it has been doing. This problem should be studied by the Finance Committee.

Sec. 7 of the Publication Committee's 1954 Report recommended that additional funds and assistance be given the Secretary General for the work of translation. This problem should likewise be studied by the Finance Committee.

In conclusion, the Publication Committee congratulates Secretary General Herbays for the high quality and large volume of work he has handled in the publication field.

Respectfully submitted,

J. H. Dellinger (*Chairman*),
W. J. G. Beynon,
M. Laffineur,
D. W. R. McKinley.

Resolutions and Recommendations adopted by the General Assembly

EXECUTIVE COMMITTEE

1. New National Committee. — The General Assembly recognized the National Committees appointed by Austria, Greece and U. S. S. R.

2. Statutary Elections. — On the proposals of the Executive Committee, the General Assembly elected :

2.1. *The Board of Officers* :

President : D. L. V. Berkner.

Past-President : Dr. P. Lejay (ex-officio).

Vice-Presidents : Dr. I. Koga,
Dr. R. L. Smith-Rose (re-elected).
Dr. G. A. Woonton.

Treasurer : Prof. Ch. Manneback (re-electred).

Secretary General : Ing. E. Herbays (re-elected).

2.2. *The Commission Chairmen* :

Commission I : Mr. B. Decaux (re-elected),
Commission II : Dr. R. L. Smith-Rose (re-elected),
Commission III : Dr. D. F. Martyn (re-elected),
Commission IV : Prof. R. A. Helliwell,
Commission V : Prof. A. C. B. Lovell,
Commission VI : Dr. S. Silver (re-elected),
Commission VII : Dr. W. G. Shepherd.

3. U.R.S.I. DELEGATES TO INTERNATIONAL ORGANIZATIONS. — The following were appointed as U.R.S.I. delegates to International Organizations.

3.1. *International Council of Scientific Unions* : Prof. Dr. B. VAN DER POL.

3.2. *Mixed Commission on the Ionosphere* : Sir Edward V. APPLETON (*Chairman*), Dr. L. V. BERKNER, Father P. LEJAY, Dr. D. F. MARTYN.

3.3. *Joint Commission on Radiometeorology* : Dr. W. E. GORDON (*Chairman*), Dr. LHERMITTE, Dr. R. L. SMITH-ROSE.

3.4. *Joint Commission on Solar and Terrestrial Relationships* : Dr. C. W. ALLEN, Mr. A. E. COVINGTON, Dr. DENISSE, Dr. D. K. MENZEL.

3.5. *U.R.S.I. Committee for C.C.I.R.* : Mr. B. DECAUX, Dr. J. H. DELLINGER, Dr. R. L. SMITH-ROSE, Prof. Dr. B. VAN DER POL.

4. ORGANIZATION OF INTERNATIONAL SYMPOSIA. — The General Assembly decided :

That international symposia of U.R.S.I. on specialized subjects related to radio science be organized approximately annually if financially feasible. Subjects for such symposia shall be proposed by the Commissions of U.R.S.I. and selected by the Board of Officers. Subjects which fall into fields of other Unions may be recommended by the Board, after consultation with chairmen of the interested Commissions, as joint symposia with those Unions,

The Board is authorized to approve financial arrangements for such symposia and shall approve the organization proposed.

It is requested by the Executive Committee that rather specialized subjects, of interest to a wide range of workers, should be chosen.

The proceedings of the symposia should be published, if possible commercially.

5. MODIFICATION TO THE SCALE OF SUBSCRIPTION. — The following regulation for the payment of national subscriptions were adopted.

(*a*) Each National Committee is free to select its annual subscription from one of the categories in the following scale :

Category	U. S. Dollars	Votes
1	125	1
2	250	2
3	500	3
4	1000	4
5	2000	5
6	4000	6

(*b*) Each National Committee is assigned the corresponding number of votes as shown in the table.

(*c*) A National Committee may transfer to a higher category at the beginning of any Fnancial Year of the Union.

Other changes of category may be made only at a General Assembly.

(*d*) The Secretary General shall inform the National Committees of the category they may care to enter ; for this purpose a list drafted by the Finance Committee has been approved by the Executive Committee.

(*e*) The revised fiscal scale shall be effective from November 1, 1957.

6. Modifications to the statutes and Bylaws. — The following modifications to the Statutes and Bylaws were adopted.

6.1. *Statutes* :

Art. 10. — The Board of Officers comprises :

(*a*) the President, the immediate Past-President, the Vice-Presidents and the Treasurer,

(*b*) the Secretary General who is the executive officer of the Union and acts as Secretary of the Executive Committee.

Art. 11. — The Board of Officers are elected by the General Assembly on the proposal of the Executive Committee, to hold office from the end of the General Assembly at which they are elected until the end of the following ordinary General Assembly. They are eligible for immediate re-election except that the President

may not normally serve two consecutive terms, and the Vice-Presidents may not normally serve more than two consecutive terms.

Art. 26. — The number of official delegates entitled to represent a National Committee at General Assemblies, and the number of votes allocated to it in Assemblies and in the Executive Committee will depend on the number of units of subscription paid annually by it, in accordance with the following schedule.

Category	Number of units of subscription	Number of delegates and votes
1	1	1
2	2	2
3	4	3
4	8	4
5	16	5
6	32	6

The value of the unit of subscription is fixed by the General Assembly.

Art. 27. — The category in which a National Committee may enter is left to its own choice. A National Committee may transfer to a higher category at the beginning of any financial year of the Union. Other changes of category may be made only at a General Assembly.

6.2. *Bylaws* :

Art. 24. — Besides the individuals mentioned in Art. 30 of the Statutes, the Honorary Presidents and Past-Presidents, and delegates of National Committees may attend the meetings of the General Assembly.

Art. 25. — With the approval of a National Committee, the President of the Union may invite any scientist from that country to attend as an observer. The President may also invite representatives of international organizations, and, on his own initiative or at the request of the President of a Commission, scientists from countries that do not adhere to the Union.

The National Committee of the host country may invite individuals of its own country to be present as observers.

6.3. *Rules for Commissions* :

Art. 11 :

(*a*) A Commission may, with the approval of the General Assembly, appoint Sub-Commissions to study particular matters within its scope.

(*b*) The Chairman of each Sub-Commission is elected by the General Assembly on the recommendation of the appropriate Commission. In general, it is expected that he will be a delegate at that General Assembly.

(*c*) The members of each Sub-Commission shall be elected by the Chairman of the responsible Commission, after consultation with its official members, if necessary by correspondence.

(*d*) The term of each Sub-Commission expires at the end of the General Assembly following its creation. If necessary, its mandate may be renewed.

(*e*) At each General Assembly the Chairman of each Sub-Commission shall present to the parent Commission a report on the work of his Sub-Commission.

COMMISSION I

ON RADIO MEASUREMENTS AND STANDARDS

Resolution nº 1

It is resolved that in view of the importance of atomic standards for frequency and time measurements it is recommended that their further development should be vigorously pursued and that their frequencies should be intercompared by means of radio transmissions and by the circulation of a single standard around a number of national laboratories . Additional Comment :

It should be noted that in making the proposed intercomparisons, the frequencies should be expressed either in terms of an atomic frequency such as that of the caesium F, m (4.0) $\leftarrow\rightarrow$ F, m (3.0) line at zero field or in terms of the unit of time scale UT2. In the latter case the time signals used should be stated so that the

interval between these signals can be expressed in terms of the caesium resonance.

If the frequency varies with any parameters external to the atom, the precise values of these parameters should be stated.

RESOLUTION N° 2

In order to establish the best means of securing a reliable worldwide service of standard frequency and time signals transmissions, it is recommended that attention be given to Resolution n° 179, Question n^{os} 140, 141, 142, and Study Programme n° 101 of the C.C.I.R. Plenary Assembly, 1956. In particular, the following questions should be studied :

1. The merits of frequencies below 100 kc/s for standard frequency transmissions and time signals.

2. Methods of recognizing without ambiguity the seconds pulses of different standard frequency transmitting stations including the case of reception at great distances.

The study should include the optimum type of time signal to be used and the advisability of synchronizing time signals from different stations.

3. The number and location of stations required for world coverage. (Any further increase in the number of stations operating in some geographical areas will result in a degradation of the service).

4. The advisability of reducing the period of tone in favor of pulses.

RESOLUTION N° 3

It is strongly recommended that the national laboratories should intercompare their standards of power measurement at frequencies in the neighborhood of 3000 Mc/s and 10 000 Mc/s. The comparisons to be coordinated by Dr. R. L. Smith-Rose, Director, Radio Research Station, Ditton Park, Slough, Bucks, England.

RESOLUTION N° 4

In order to avoid confusion between the terms radio field strength and radio field intensity, it is recommended that :

1. *Radio Field Strength* refers to the magnitude of the electric

or magnetic field vector (E or H) at a given location resulting from the passage of radio waves.

2. *Radio Field Intensity* refers to the power density of electromagnetic waves passing through a surface normal to the direction of propagation,

RESOLUTION N° 5

In order to stimulate international and national efforts in the standardization programs of high-frequency and microwave quantities such as power, impedance, voltage, current, attenuation, field strength, noise, etc., the XIIth Assembly of U.R.S.I. recommends to members of the U.R.S.I., the I.E.C., the C.C.I.R., the I.S.O., and other international groups concerned with electrical standards that the following be done :

(*a*) Compile, as soon as possible, a table of *rf* quantities including those distributed in time, frequency and space to be standardized. This table shall specify dynamic ranges, frequency ranges and corresponding desirable practical accuracies for primary standards. It shall also specify desirable priorities for the various quantities and corresponding ranges.

(*b*) Information and tabular material, as requested in (*a*) above, shall be forwarded to the President of Commission I, U.R.S.I., for consolidation and possible adoption at the XIIIth U.R.S.I. General Assembly. It is desirable that this table be brought up to date at successive General Assemblies.

RESOLUTION N° 6

In view of the progress made since the XIth General Assembly in the measurement of the velocity of electromagnetic waves, it is recommended that in radio engineering problems its value in vacuum be taken as :

$$299\,792.5 \pm 0.4 \text{ km/s}$$

COMMISSION II
ON RADIO AND TROPOSPHERE

1° *It is recommended by Commission II at the XIIth General Assembly that* :

(*a*) The extent of the dependence of scattered signals on latitude,

climate and terrain should be further studied by means of observation in differing geographical areas.

(*b*) In particular, measurements of field strengths from high-power transmitters should be made at great distances and for various frequencies, polarization, antenna heights and gains, and various types of terrain. Use of aircraft in such measurements is recommended.

(*c*) Propagation studies should be extended to include investigation of pulse distortion, phase stability, fading rates, and diversity properties of the signal.

(*d*) Simultaneous meteorological measurements designed to improve understanding of the propagation mechanism are desirable.

(*e*) Quantitative knowledge of the means of relating the above findings to practical radio results should be extended, especially in the direction of providing satisfactory approximations.

2° In view of the importance of conditions in the lower atmosphere to the propagation of the shorter radio waves, it is recommended that U.R.S.I. take steps to insure that national meteorological authorities are aware of the need of radio scientists for meteorological observations ; and that such observations should be organized so as to provide as much information as possible for application in the radio field. It is recommended that national meteorological authorities should be encouraged to :

(*a*) Perform more detailed meteorological measurements, including those with airborne equipment, with emphasis on the study of the fine structure of the atmosphere. Special attention should be given to the detailed variation of the refractive index in the region where this index undergoes significant changes. The use of the refractometer for such measurements is strongly recommended.

(*b*) Complete meteorological data of the nature described under (*a*) for the purpose of using these data as a help in prediction, on a statistical basis, of the propagation characteristics to be expected in various geographical regions.

3° It is recommended that, whenever possible, meteorological measurements of a sufficiently detailed character to throw light on the mechanism of propagation, be carried out in conjunction

with programmes of propagation measurements. It is suggested that several varieties of atmospheric phenomena and methods of study are directly or indirectly germane to tropospheric radio propagation ; hence, multi-purpose meteorological and radio signal measuring programmes are recommended as mutually beneficial and economic.

4° It is recommended that the mathematical problem of the propagation of electromagnetic waves in an inhomogeneous medium with a refractive index which is a function of the height above a spherical earth, be further investigated with a view to determining the fields transmitted around the earth. The mathematical investigation should in particular, bring better knowledge of the eigen values which belong to the various modes, and a better determination of the height gain functions. Alternatively any other method which permits the determination of the fields exactly or with an estimate of the error, should be pursued.

5° Commission II, in noting the C.C.I.R. Questions n° 101, 136, 137 and 138, and the Study Programmes n° 55, 57, 79, 90 and 91 reports that more than two thirds of its sessions at the XII General Assembly were devoted to active discussion of work relating directly to these subjects from many different organizations. It is clear that useful results are being achieved, and will be communicated to C.C.I.R. by various administrations before the next Plenary Meeting.

6° Commission II concurs unanimously with the following statement of purpose of the joint Commission on Radio Meteorology as formulated at its meeting of August 16, 1957 : that the 1957 meeting of the joint commission had provided a successful forum in which specialists in radio science, meteorology, and physics had a unique opportunity to describe their experiences and exchange knowledge about phenomena in the lower atmosphere in which they had a mutual scientific interest and the follwing resolutions were adopted unanimously :

(*a*) That the Joint Commission should continue as a forum with a reasonable balance of radioscientists, meteorologists, and as may be necessary other physicists, in which the radiometeorologists can exchange knowledge and experience.

(*b*) That the programme for the immediate future should be :

(1) study of vertical and horizontal air movements and refractive index structure including formation of clouds and precipitation and application of the results to radio wave propagation and meteorology,

(2) study of electrical fields in the atmosphere with special reference to thunderstorms.

(*c*) That the constituent Unions be invited to review their representation on the Commission and make fresh appointments where necessary.

(*d*) That the next meeting of the Commission be held in 1960.

(*e*) That the papers for presentation at the next meeting be submitted to the President of the Commission for approval three months before the meeting.

(*f*) That the Commission wishes to convey its warmest gratitude to the President of New-York University and his staff, particularly Prof. Morris Kline for the facilities, assistance, and hospitality provided in connection with the Commission's meeting.

7° During the I.G.Y. the needs of radio scientists studying tropospheric wave propagation should continue to be met by the following program :

(*a*) Radiosonde data up to heights as high as practicable should be published in as much detail as the precision of the instrument permits. During World Meteorological Intervals the number of soundings should be at least four per day.

(*b*) It is suggested that where possible supplementary observations should be made of meteorological data at lower levels using captive balloons or masts.

(*c*) Where possible airborne microwave refractometer soundings should be made in various air masses to ascertain the characteristics of the air masses with respect to the vertical distribution of refractive index and the scale and intensity of its fluctuations.

(*d*) The attention of the meteorologists should be drawn to the refractometer as a rapid instrument for the determination of water vapor content when used in conjunction with a temperature measuring element. The refractometer soundings described in

(*c*) above have a direct usefulness to the meteorologists in this regard.

COMMISSION III

ON IONOSPHERIC RADIO

The following nine Resolutions formulated by the Mixed Commission on the Ionosphere at its Meeting in New-York (August, 1957), were subsequently endorsed by U.R.S.I. at the XIIth General Assembly at Boulder.

1. *Ionospheric Current Systems* :

(i) The MCI expresses the hope that new determinations of the Sq and S_D electric current systems in the ionosphere will be made on the basis of the IGY magnetic records.

(ii) The MCI invites the International Association of Geomagnetism and Aerology (I.A.G.A.) to consider the possibility of determining the latitudes of the foci of the Sq current systems at one or more longitude on as many days as possible during the I.G.Y.

2. *Region E parameters.* — The MCI reaffirms its earlier resolutions on the need for accurate scaling and timing of region E parameters. It recommends that recordings of the E-region trace on ionograms should be made on expanded frequency scales. It further recommends that especial attention should be given to the measurement of h'E at stations located near the magnetic equator.

3. *Ionospheric Tidal Phenomena.* — The MCI calls attention to the need for studies during the I.G.Y. of lunar tidal oscillations in the E and sporadic E layer parameters — h'E, fE, h'E*s*.

4. *Height and Frequency Scales of Ionograms.* — The MCI recommends that during the I.G.Y., the U.R.S.I World Soundings Sub-Committee should be charged with the control of relative and absolute scales of height and frequency

5. *Measurements of horizontal ionospheric movements.* — The MCI recommends that there should be the fullest co-operation between stations studying horizontal movement so that the world pattern of such motion may be elucidated.

6. *Electron density/height profiles* (N, h). — The MCI recommends that organisations which undertake the calculation of N, h profiles should interchange sample ionograms and the corresponding calculated profiles, so as to ensure agreement on the results obtained by different methods.

7. *Rocket investigations in Auroral latitudes.* — The MCI recommends that a more intensified small rocket programme should be carried out in auroral latitudes to study particle and other radiation at levels below 90 km.

8. *Ionospheric irregularities.* — The MCI recommends that groups observing rapidly moving ionospheric irregularities should be encouraged to continue this work and to interchange results. It is also strongly recommended that studies of all ionospheric movements should be arranged on a local or regional basis.

9. *Nomenclature.* — The MCI recommends :

(i) that the total ionisation content per unit column in that part of an ionised region below its peak be designated the « sub-peak electron content » of the region.

(ii) that the present terminology on « whistlers » (« nose-whistlers» etc.), should be regarded as tentative and that a study of a more appropriate terminology should be immediately undertaken.

(iii) that the letter A be used to designate auroral ionisation resulting directly or indirectly from the entry into the earth atmosphere of solar particles : also that the subdivisions of this ionisation be indicated as follows.

A*a* auroral ionisation due to primary atomic particles.

A*e* auroral ionisation due to electrons.

A*x* auroral ionisation due to X-radiation.

A*u* auroral ionisation due to ultra-violet radiation.

A*r* auroral ionisation due to photo-detachment by red radiation.

The General Assembly also adopted the following Resolutions :

10. *Proposal for Joint Study Group.* — Recognising the inter-relation that exists in the ionosphere between electro-magnetics, hydro-magnetics and fluid mechanics, Commission III recommends that encouragement be given to a Joint Study by workers in fluid mechanics and in geophysics, with a view to encouraging, on the

one hand, the solution by fluid mechanics workers of unsolved problems in geophysics, and encouraging, on the other hand, the application in geophysics of established knowledge in fluid mechanics.

11. *Rocket and Satellite Experiment.* — Commission III of U.R.S.I. encourages member countries to undertake Rocket and Satellite programmes of the atmosphere and of the surrounding regions of space and urges collaboration between nations engaged in such enterprises.

12. *Analysis of I.G.Y. Data.* — If the full benefit of the I.G.Y. Programme is to be realised, it is necessary to make provision for extended studies of the data by qualified workers. U.R.S.I. strongly urges those Government agencies which have financed the prosecution of the I.G.Y. programme now to allocate adequate funds for the purpose of supporting scientists wishing to analyse the data obtained.

13. *Symposia.* — Commission III of U.R.S.I. welcomes and endorses the proposal of the Executive Committee to hold Symposia on special topics of radio science at approximately yearly intervals. Bearing in mind however, that most scientists and organisations working on ionospheric radio are heavily involved in I.G.Y. activities until the end of 1958, and consequently have no time to prepare such Symposia successfully, it is proposed that no Symposia on matters concerning Commission III shall be held before the middle of 1959.

14. *Theoretical Studies of Electron density/height profiles.* — Whilst recognising the great advances which have been made in the calculation of electron density/height profiles U.R.S.I. now recommends that the theoretical problem in its widest sense (including anisotropy and collision of electrons) of the determination of the distribution of ionisation with height should be further studied. It is part of this problem to specify precisely what information, measurable at the ground, is needed for the unique theoretical determination of the distribution. The general study would also be of value for further investigations of the troposphere.

15. *Sub-Commissions.* — Commission III recommends :

(i) that Sub-Commission III*a* on Ionospheric Observations and Reduction of Data, Sub-Commission III*b* on Wave Interaction, and Sub-Commission III*d* on Magneto-ionic Nomenclature be dissolved.

(ii) that Sub-Commission III*c* on Study of Propagation Time of Radio Signals continue in being under the chairmanship of Prof. Boella and with the same membership.

(iii) that a new Sub-Commission III*e* on Ionospheric Indices of Solar Activity be established under the chairmanship of of Dr. W. J. G. Beynon and with the following membership : M. C. M. Minnis.

16.*Special Report.* — Commission III recommends that a Special Report on « Radio Observations of the Aurora » be prepared by a Committee with the following membership : Dr. J. H. Chapman (*Chairman*), Professor A. C. B. Lovell, Dr. A. M. Peterson, M. Owren, Prof. H. G. Booker, Dr. Ellyett and Dr. L. Harang.

COMMISSION IV

ON RADIO NOISE OF TERRESTRIAL ORIGIN

Recommendation nº 1

Measurement of Atmospheric Noise

U.R.S.I. Commission IV recommends that the following comments on the measurement of atmospheric noise be communicated to the C.C.I.R.

« U.R.S.I. has considered the C.C.I.R. question « What are the most easily measured characteristics of terrestrial radio noise from which the interference to different types of communication system can be determined » and has also considered C.C.I.R. Study Programme nº 96 dealing with the measurement of atmospheric radio noise. The following comments on these topics are offered to the C.C.I.R.

» Considerable progress has been made during the last few years in the measurement and description of the amplitude characteristics of atmospheric noise. Although time characteristics are also required for a complete statistical description of the noise, useful relationships have been found between the amplitude characteristics alone and the interference caused by the noise to many types of radio service.

» There is general agreement on what amplitude characteristics should be measured, and members of U.R.S.I. are being encouraged to study these characteristics at many more locations, in accordance with the recommendations contained in the Annex. »

RECOMMENDATION N° 2

U.R.S.I. Special Report on Atmospheric Noise

Commission IV recommends that a working group be set up under the Chairman of Commission IV to prepare an U.R.S.I. special report on the measurement of the characteristics of atmospheric noise and their relation to radio interference. This report should be based on the material collected to formulate a reply to C.C.I.R. questions.

RECOMMENDATION N° 3

Symposium on naturally-occuring VLF Phenomena

Considering the wide current interest by members of U.R.S.I. Commissions III, IV and V in the study of whistling atmospherics and related types of very low frequency atmospheric noise, Commission IV recommends that consideration be given to the possibility of arranging a symposium on this subject before the XIIIth General Assembly.

RECOMMENDATION N° 4

Collection of Atmospheric Noise Data from Astronomical Observatories

Commission IV recommends that a communication be addressed to the International Astronomical Union, expressing the belief that measurements of atmospheric radio noise are being made at many astronomical observatories throughout a large part of each

day, and requesting that the results of any such measurements be made available to radio workers. The communication should further suggest that there should be consultation between the I.A.U. and U.R.S.I. to ensure that the measurements are made in as useful and uniform a manner as possible for radio as well as for astronomical applications.

Recommendation nº 5

Cooperative Measurements of the Waveforms of Atmospherics

Commission IV recommends that where groups of workers have coordinated their work on the recording of waveforms of atmospherics with the object of showing their variations from place to place, and there such workers desire to publish a joint account of their combined work, U.R.S.I. should facilitate this work by providing means for exchanging data and for joint consultation.

Recommendation nº 6

Working Group on Terminology relating to VLF Noise Phenomena

Commission IV recommends that a working group be set up under the Chairman of Commission IV to review continually the terminology used in the description of whistlers and related phenomena, and to make further recommendations on this topic to the XIIIth General Assembly.

Recommendation nº 7

Provisional Terminology relating to VLF Noise Phenomena

Until the Working Group set up under Recommendation 6 has reported, Commission IV recommends that the following terminology be adopted tentatively in work on whistlers and related phenomena.

Atmospherics : Natural electrical disturbance originating in the earth's atmosphere. Atmospherics may be subdivided into the following types :

A. Spherics : Atmospherics which originate in, and are propagated through, the space between the earth and the ionosphere.

B. Whistlers : Atmospherics which originate in lightning discharges and which are propagated through the ionosphere along dispersive paths.

C. VLF Emissions : Atmospherics which are *not* produced by lightning. They are usually associated with magnetic disturbance and have often been referred to loosely by the term « dawn chorus ». The following sub-groups are recognized :

1. *VLF Hiss* : A relatively steady VLF emission generally exhibiting a frequency-dependent amplitude spectrum. Its spectrum and intensity may change slowly (period of several seconds or more) with time.

2. *Discrete events* : Well-defined VLF emissions having durations of the order of a few tenths to several seconds. A definite and repeatable frequency-time relation in often observed.

3. *Chorus* : A series of discrete VLF emissions, often overlapping, with time separations of less than one second.

Annex to Recommendation n° 1

Prepared by : W. Q. Crichlow, *Chairman*,
G. Foldes, F. J. Hewitt, F. Horner, H. Shinkawa
and A. W. Sullivan

I. — Measurements

It would be highly desirable to obtain detailed statistical information on the amplitude-probability distribution of the instantaneous envelope voltage, the various time functions, and the direction of arrival of the noise at many locations throughout the world. However, since continuous detailed measurements of this type at all frequencies and at a large number of stations become prohibitive because of the complexity of the equipment involved and the large number of personnel necessary to carry out the observations, it is recommended that these complete studies of the detailed noise characteristics be confined to a few selected locations with continuous measurements of one or more simple parameters at a larger number of stations.

The amplitude-probability distribution has been measured at a number of locations and three proposals have been made for the mathematical representation of the distribution. The simplest of

these is the log-normal distribution, which can be completely represented by means of two parameters, the average logarithm and the standard deviation, expressed in logarithmic units. By simple mathematical relationships, it can also be expressed in terms of the average power and the average envelope voltage.

Another representation is of the form :

$$Q(v) = \left[1 + \left(\frac{2v}{\bar{v}}\right)^q\right] - 1$$

where Q (v) is the fraction of the time for which the envelope exceeds different voltages v, $\bar{v}$ is the average envelope voltage and q is a constant determined experimentally. This expression can be evaluated in terms of three measured parameters.

The third form is represented by the following expressions :

$$Q(v) = e^{-y^2}$$

$$v = a_1 y + a_2 y^{\frac{b+1}{2}} + a_3 y^b$$

$$b = 0.6 \left[20 \log_{10} \frac{v^{\text{rms}}}{v}\right]$$

The constants in these expressions can be evaluated by means of three measured parameters such as the average power, the average envelope voltage, and the average logarithm of the envelope voltage. Although this expression is more complex and requires the measurement of one moment more than the log-normal distribution, it has the advantage of being able to represent the complete amplitude time distribution of the noise over a much wider range of probabilities.

Since all three of these representations of the amplitude time distribution can be described by means of measured moments, it is recommended that measurements be made at as many locations as possible of the average power, the average envelope voltage, and the average logarithm of the envelope voltage. If only one parameter is to be measured, priority should be established in the order given. The number of parameters actually necessary to describe the true distribution will be determined by the variability of shape that is observed from one place to another and as a function of time and frequency. If a sufficient number of systematic tendencies can be found for the shape of the distri-

bution, then fewer moments will be required to show the variability.

It is recommended that studies be continued of the relationship between the various parameters, such as the ratio of the r. m. s. to the average under all conditions, i. e. as a function of time, frequency, and location. Studies of the influence of band on all of the parameters as well as the statistical distributions are recommended.

It is certain that measurements of some time functions of the noise such as lengths of pulse or of noise bursts will be required for a full description, but it is not present clear which of these should be recommended.

Direct measurement of the moments is preferred instead of measurements of the Thomas type, but it is recommended that the operation of existing Thomas stations be continued until they can be replaced with the recommended measurements.

Although DF measurements are desirable at certain selected locations, it is recommended that omnidirectional antennas be used at most stations, in order to insure uniformity of results.

In making any measurements of noise, it is extremely important to carefully state all conditions of measurement so that observations by different experimenters can be interrelated.

II. — Techniques

A. — *Probability Distributions*

In making detailed statistical measurements on the instantaneous noise envelope voltage, it is recommended that measurement should be based on counting techniques, for example, using 10 kc/s pulses gated by the noise. These are the most versatile, since counting equipment can readily be adapted to the measurement of a number of parameters, such as the amplitude probability distributions, the distributions of the pulse lengths, and the intervals between the pulses.

The equipment necessary for making such measurements will generally contain the following components :

1. antenna,
2. calibrating signal,
3. calibrated attenuator,

4. receiver,
5. selective circuits of known effective bandwidth,
6. envelope detector,
7. amplitude discriminator,
8. gating circuits,
9. signal generator (usually about 10 kc/s),
10. one or more frequency counters.

The design of the receiver must be such that its recovery time is very short upon overload by high amplitude pulses. Except for this limitation, there are no severe dynamic range or linearity requirements. The receiver noise, of course, must be lower than the level of external noise that is to be measured.

The distributions are obtained by gating the 10 kc/s signal on for the period of time during which the noise level exceeds the threshold of the gating circuits, and by changing the amount of the attenuation at the input of the receiver in known steps. Various lengths of counting time are used at the different threshold levels. In general, 100 seconds is used for values of 5 % and greater, 200 seconds for values in the range of 0.0005 %, and 300 to 1000 seconds for values less than 0.0005 %. In general, a total of about 10 minutes is required to obtain all but the last three low percentage readings which themselves may take 10 to 20 minutes in order to obtain statistically constant data. The total time required is a function of the type of noise being measured. A longer time is required for noise with a large dynamic range.

B. — *Individual Parameters*

1. *Average Envelope Voltage.* — The basic equipment for measuring the average envelope voltage is as follows :

(*a*) antenna,
(*b*) calibration source (signal generator or noise diode),
(*c*) frequency selective circuits of known effective bandwidth,
(*d*) envelope detector (detector capable of following the peaks of the I.F. cycles at the audio-frequency rate),
(*e*) integrating circuit (usually an RC circuit with a time constant of 100 seconds or more),

(*f*) AGC or variable attenuator circuit (controlled by the integrated voltage),

(*g*) recorder circuit (the recorder should indicate the magnitude of the control voltage which is calibrated in terms of the input signal level).

It is essential for the receiver to be linear over the important dynamic range of the noise being observed, for a fixed gain, so that the noise envelope is undistorted at the detector output. This requires an instantaneous dynamic range of 40 db or more. The required dynamic range is a function of the type of noise being measured and the bandwidth of the equipment. The narrower the bandwidth, the smaller the dynamic range. Usually bandwidths of the order of 300 cycles to 1000 cycles are used. The gain stability of the equipment must be adequate to insure repeatability of calibrations. The noise figure of the equipment must be as low as possible to minimize contamination of low noise levels.

2. *Average Power.* — The required circuitry for measuring the r.m.s. voltage, or noise power, is similar to that required for average envelope measurements, except that just prior to detection a square law circuit is used. This circuit can consist of two tubes with the grids in push-pull and the plates in parallel ; thus, producing in the plate circuit a voltage at twice the input frequency and with an amplitude proportional to the square of the input voltage. The amplifier and detector that follow must have a much larger dynamic range in order to handle the squared values without distortion. Using a bandwidth of about 300 c/s, a dynamic range of 80 db or more is required ; however, much smaller bandwidths can be used for the power measurement, since the power is directly proportional to bandwidth regardless of the type of noise. Using a bandwidth of the order of 1 c/s, the required dynamic range is reduced to about 40 db or less, since for these bandwidths the noise has the characteristics of thermal noise and approaches a Rayleigh distribution. The time constant used will depend to a certain extent on the bandwidth ; however, a time constant of 500 seconds seems to give adequate smoothing.

3. *Average Logarithm.* — The equipment required for measuring the average logarithm is again very similar to the equipment for average envelope measurements. The principal difference is that

a logarithmic amplifier is inserted between the envelope detector and the integrating circuit. A convenient circuit is a triode operating at zero bias and with a high value of grid resistance so that the plate current is an exponential function of the applied grid voltage. With this type of measurement, a time constant of the order of 50 seconds has proven satisfactory. It should be noted that the logarithmic amplifier must be capable of operating at the envelope frequency, i. e. the integration must occur after the logarithmic circuit rather than prior to or within the logarithmic circuit. It should also be noted that the gain control voltage must be obtained after integration rather than before integration.

COMMISSION V

ON RADIO-ASTRONOMY

Resolutions

1. Sub-Commission V*a* on « continuous measurements of solar radio emission » should be discontinued.

2. A member of Commission V should be appointed to the Ursigram Permanent Committee.

3. Sub-Commission V*c* on « the basic solar index » should be continued with the following membership :

Chairman : S. Chapman.

Members : J. Bartels,
A. E. Covington,
M. Nicolet,
M. Waldmeier,
S. F. Smerd,
J. F. Denisse,
C. M. Minnis,
H. Dodson Prince,
R. N. Bracewell,
A. Maxwell.

4. Sub-Commission V*d* on « Standards » should be continued with the following membership :

Chairman : C. Seeger.

Members : A. E. Covington.
F. T. Haddock,
M. Laffineur,
D. A. Macrae,
C. H. Mayer,
F. G. Smith,
J. L. Steinberg,
T. Hatanaka,
R. Hanbury Brown.

5. The Commission endorses the following recommendation put forward by Sub-Commission V*d* :

« There is now general agreement on the desirability of establishing certain of the stronger discrete sources as members of a standard sequence of flux density. To achieve this objective, it is desirable that U.R.S.I. Commission V and I.A.U. Commission 40,

(1) designate the following sources as members of a standard sequence of flux density,

23N5A (Cas A)	12N1A (Vir A)
19N4A (Cyg A)	16N0A (Her A)
05N2A (Tau A)	09S1A (Hyd A)

(2) call the attention of all radio astronomy observatories to the urgent need for more accurate values for the absolute flux densities of the above sources.

(3) recommend that, in observational studies of discrete sources, greater attention be paid to obtaining accurate, well defined intensity ratios between the objects under observation and the members of the above standard sequence.

(4) recommend that persons making high resolution « pencil-beam » surveys, pay particular attention to the regions surrounding the above sources and publish their findings in the form of detailed maps, perhaps 30 × 30 degrees and centered on the individual sources.

Commission V proposes that this recommendation should be forwarded to the I.A.U. for consideration by Commission 40.

6. Commission V expresses its thanks to the I.A.U. and C.C.I.R. for considering resolutions 4 and 5 adopted by Commission V at the XIth General Assembly in 1954. Once again it

insists on the absolute necessity that those observatories engaged in radio-astronomy which are troubled by interference should receive the backing of the authorities in their own and neighbouring countries.

1. A new Sub-Commission V*e* on « Frequency Allocation » should be established. This Sub-Commission is charged with preparing recommendations to be submitted through the appropriate authorities to the International Telecommunication Union at their meeting in 1959. The membership of this Sub-Commission is to be :

Chairman : F. T. Haddock (U. S. A.).

Members : E. J. Blum (France).
A. Hewish (U. K.),
V. Vitkevitch (U. S. S. R.),
W. N. Christiansen (Australia),
A. H. de Voogt (Netherlands),
T. Hatanaka (Japan),
L. Erikson (Norway),
F. Becker (Germany),
A. E. Covington (Canada),
G. Righini (Italy),
J. Tuominen (Finland),
O. E. H. Rydbeck (Sweden),
R. Coutrez (Belgium),
A. P. Mitra (India).

8. A working party, consisting of the Presidents of Commissions III and V, should examine the division of subjects between these two commissions.

9. Commission V recommends that U.R.S.I. should assent to the request by I.A.U. to sponsor a joint Symposium on Radio Astronomy in France just prior to the General Assembly of I.A.U. in 1958.

It recommends that the subjects matter should be restricted to those aspects of radio astronomy which are particularly of astronomical interest ; it should include solar, galactic and extra-galactic radio emission together with a short session on radio

studies of other bodies of the solar system. The number of scheduled speakers should be restricted so as to leave adequate time for discussion.

It also recommends that the proceedings should be published in book form.

The Commission suggests that the following persons should serve on a joint U.R.S.I.-I.A.U. organizing committee :

Chairman : J. L. PAWSEY (President of Commission 40 I.A.U.).

Secretary : F. T. HADDOCK,

Members : The Chairman of Commission V of U.R.S.I.
J. F. DENISSE,
V. VITKEVITCH,
R. MINKOWSKI,
A. C. B. LOWELL,
H. C. VAN DE HULST,
R. N. BRACEWELL.

J. L. PAWSEY, representing the I.A.U. at this General Assembly, has informed Commission V that he considers these proposals entirely acceptable to the I.A.U.

COMMISSION VI

ON RADIO WAVES AND CIRCUITS

1. The Commission notes with regret the passing of Prof. Marcel Bayard, an outstanding representative of the French National Committee in the field of Circuit Theory.

Resolved that a memorial be published in the Proceedings of the XIIth General Assembly.

2. Resolved that National Committees be urged to add to their membership circuit and communication engineers interested in operational problems of communication circuits to supplement the current theoretical work in the circuit field.

3. Resolved that National Committees be urged to add to their membership engineers and scientists interested in propagation in anisotropic media to contribute to the work of Commission VI in such areas as gyrators, isolators, etc.

4. Recommendation on organization of programme for Commission VI for the XIIIth General Assembly : The main body of the programme shall consist of discussion sessions on chosen topics introduced by invited papers, and that there shall be one or more sessions on contributed papers. Contributed papers shall be presented only if the author is present.

5. That a working group be named to study and report on the classification of surface waves.

6. That Commission sponsor an international symposium on Electromagnetic Theory in 1959 ; Toronto, Canada is being considered as the location.

7. That work on the monograph on communication systems be continued during the following three year period.

Recommendations for future work

1. The field strength in the neighborhood of antennas and obstacles under time-harmonic and transient conditions.

2. Wave propagation in anisotropic media.

3. The theory of surface wave and leaky wave antennas.

4. Calculation of the diffraction fields for dimensions of bodies in the resonance region.

5. Study of synthesis problem for actual antennas and scattering systems.

6. Scattering from periodic and « disturbed » periodic structures.

7. Study of broad-band antennas.

8. Study of design problems in large aperture antennas ; comparison between reflector antennas and arrays.

9. Application of communication theory principles to antenna design and scanning problems.

U.R.S.I.-I.G.Y. COMMITTEE

1. The U.R.S.I./I.G.Y. Committee recommends that the contributions to the meeting devoted to the I.G.Y. during the morning of August 27th should be published by U.R.S.I.

2. The Committee recommends that its future constitution should be as follows :

Sir Edward Appleton (*Chairman*),
Dr. L. V. Berkner (*Vice-Chairman*).
Dr. W. J. G. Beynon (*Secretary*).
Father P. Lejay.
Prof. H. G. Booker,
Dr. W. Dieminger,
Dr. N. Fukushima,
Ing. E. Herbays,
Mr. D. Lépéchinsky,
Dr. D. F. Martyn,
Mr. M. Nicolet,
Dr. N. V. Pushkov,
Mr. J. A. Ratcliffe,
Mr. A. H. Shapley,
Dr. R. J. Slutz,
Dr. R. L. Smith-Rose.

3. *The Committee is well aware of the plans already formulated in many institutions throughout the world for the scientific elucidation of I.G.Y. radio observations by way of theoretical study. Nevertheless, in view of the vast and unique opportunity for geophysical comprehension which such observations provide, the Committee invites all bodies which sponsor scientific research to consider the possibility of instituting special I.G.Y. Fellowships and Studentships — of all ranges of seniority, from professorial downwards — for the prosecution of such theoretical research in I.G.Y. World Data Centers, universities and similar institutions on an individual or group basis.*

The Committee warmly commends the action of Unesco in instituting special studentships for the operational phase of the I.G.Y., and trusts that the same body will continue to support individual scholars, in the same way, during the post-I.G.Y. stages of scientific elucidation.

Finances

Report of the Finance Commission to the Executive Committee

Appendix I : Statements of receipts and expenditures.
Appendix II : U.R.S.I.-Unesco accounts.
Appendix III : Publication accounts.
Appendix IV : Accounts for the 1954 General Assembly.
Appendix V : General financial statement.
Appendix VI : Providend Fund.
Appendix VII : Travel and subsistence.
Appendix VIII : Budgetary estimates.

1. — Statements of Receipts and Expenses

The Finance Commission examined the accounts for the fiscal years 1954, 1955 and 1956 submitted by the Secretary General and the Treasurer and checked by Messrs Herbert Gimson and Sons, Chartered Accountants, London, in accordance with the decision reached at The Hague ; they include :

1. General statements of receipts and expenses (Appendix I),
2. U.R.S.I.-Unesco accounts (Appendix II),
3. Publication accounts (Appendix III),
4. Accounts for the 1954 General Assembly (Appendix IV).

The Commission recommends the adoption of these accounts. Appendix V gives in round figures a general view on the accounts. The assets on November 1st, 1956, are as follows :

Reserve fund ...	1 000 000,00	Bank	1 770 855,73
Reserve for General Assemblies .	537 302,27	Cash	50 720,21
Available	292 219,67	Debtors	7 946,00
Total ..... F. B.	1 829 521,94	Total ..... F. B.	1 829 152,94

2. — Use of available assets

The Commission suggests to allocate the available assets on November 1st, 1956 (F. B. 292 219,67) to a providend fund for the General Secretariat staff. This fund would be supplied, during the three fiscal years 1958, 1959 and 1950 by annual budgetary instalments of B. F. 70 000 (1) each. If these proposals were accepted, the schedule of the providend fund would be as shown in Appendix VI.

3. — Levy on the Reserve Fund

Taking into account that the new scale of subscriptions may give its full effect with some delay, the Finance Commission suggests to authorize the Treasurer and the Secretary General, jointly and with the agreement of the Board of Officers, to make temperary levies on the Reserve Fund, for a total amount not exceeding B. F. 250 000, in order to meet the expenses provided for new activities. Such levies should be reimbursed to the Reserve Fund as soon as the balance in hand would allow it.

4. — Investment in Belgian State Loans

The Commission proposes to authorize jointly the Treasurer and the Secretary General to invest in Belgian State loans half of the Reserve Fund. They should keep the Board of Officers informed.

5. — Travelling expenses

The Finance Commission recommends the adoption by U.R.S.I. of the new scale of travelling expenses already adopted by I.C.S.U. and given in Appendix VII. The Commission also recommends that scale to be used for the present General Assembly.

6. — Subscriptions

For what concerns the new subscriptions, proposals have already been submitted to the Executive Committee together with a list of subscriptions suggested to National Committees.

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(1) This amount was reduced to B. F. 50 000 by the Board of Officers (March, 1958).

7. — Budgetary estimates

Taking into account the increase of subscriptions and of the activities of U.R.S.I. which will lead to an increase of the salaries of the General Secretariat staff, together with the instalments to the Providend Fund, as suggested in 2, the Commission proposes for 1958 and the following fiscal years, the adoption of the budgetary estimates as given in Appendix VIII.

8. — Publication in the Proceedings of the XIIth General Assembly

The Commission suggests to publish in the Administrative Proceedings of the XIIth General Assembly the present Report and the Appendices, the general statements for the fiscal years 1954, 1955 and 1956 together with the U.R.S.I.-Unesco accounts.

Boulder, 3rd September 1957.

B. D. H. Tellegen, *President*,
B. F. Decaux,
A. H. Shapley,
R. L. Smith-Rose.

Appendix Ia

STATEMENT OF RECEIPTS AND EXPENDITURES FOR 1954

(10 months — January 1 — October 31, 1954)

Belgian francs

Receipts

Subscriptions		551 893.65	
Publications :			
Sale of publications	15 747.24		
Subscriptions to Information Bulletin	3.691.90		
		19 439.14	
Supplementary subvention for publications		20 162.00	
Bank deposit interest		14 700.00	
			606 194.79

Expenses

Honoraria and salaries	176 394.—
Social laws, accidents insurance	14 101.—
Providend Fund	10 000.—
Office equipment	8 711.25
Postage, Telephone, Telegrams	13 244.75
Office rent, heating, cleaning, fire insurance	19 905.50
Furniture, stealth insurance	126.—
Travelling expenses	4 020.—
Bank and exchange expenses	154.—
General Assemblies and Meetings	145 740.24
Publications	119 522.70
Miscellaneous	170.—
	512 089.44

Balance in hand on October 31, 1954 : F. B. 94 105.25

Appendix Ib

STATEMENT OF RECEIPTS AND EXPENDITURES FOR 1955

(November 1, 1954 — October 31, 1955)

		Belgian francs
RECEIPTS		
Subscriptions		777 294.18
Publications :		
Sale of publications	28 406.53	
Subscriptions to Information Bulletin	4 340.48	
		32 747.10
Bank deposit interest		16 391.—
		826 432.19
EXPENSES		
Honoraria and salaries		222 079.—
Social laws, accidents Insurance		16 157.50
Providend Fund		10 000.—
Office equipment		11 503.25
Postage, Telephone, Telegrams		13 855.—
Office rent, heating, lighting, cleaning, fire insurance		26 982.—
Furniture, theft insurance		6 080.—
General Assemblies and Meetings		31 068.65
Representational expenses		4 780.—
Allowance to Commission Chairmen		4 592.—
Travelling expenses		4 569.—
Bank and exchange expenses		419.—
Publications (over Unesco subvention)		49 238.10
I.C.S.U. subscription		5 991.—
Miscellaneous		1 170.—
		408 484.50

BALANCE IN HAND ON OCTOBER 31, 1955 : F. B. 417 947.69

Appendix Ic

STATEMENT OF RECEIPTS AND EXPENDITURES FOR 1956

(November 1, 1955 — October 31, 1956)

Belgian francs

Receipts

Subscriptions		694 840.59
Publications :		
Sale of publications	40 948.10	
Subscriptions to Information Bulletin	9 144.52	
		50 092.62
Bank deposit interest		26 248.—
		771 181.21

Expenses

Honoraria and salaries	247 500.—
Social laws, accidents insurance	17 317.—
Providend Fund	10 000.—
Office equipment	6 391.—
Postage, Telephone, Telegrams	12 336.—
Office rent, heating, lighting, cleaning, fire insurance	23 751.—
Furniture, theft insurance	14 680.—
General Assemblies and Meetings	8 266.75
Representational expenses	2 257.—
Allowance to Commission Chairmen	1 054.—
Travelling expenses	1 445.—
Bank and exchange expenses	724.90
Publications (over Unesco subvention)	182 521.—
I.C.S.U. Subscription	7 831.—
Miscellaneous	170.—
	536 244.65

Balance in hand on October 31, 1956 : F. B. 234 936.56

Appendix IIa

U.R.S.I.-UNESCO ACCOUNT FOR THE FISCAL YEAR 1954

Belgian francs

Receipts

Grant for publications	118 407.90
Grant for General Assembly	98 625.22
	217 033.12
Transfer of the balance to U.R.S.I.	243 551.07
	460 584.19

Expenses

A) Publications :		
1. Preparation	18 632.—	
2. Printing	200 630.—	
3. Postage	13 093.60	
		232 355.60
B) General Assembly 1954 :		
1. Transportation and subsistence	117 766.01	
2. Organizational expenses :		
a) General	8 393.58	
b) Preparation of documents :		
1. Stationery	43 382	
2. Typing	26 600	
3. Reproduction	28 319	
4. Postage	3 768	
	102 069.—	
	110 462.58	
	228 228.59	
		460 584.19

Appendix IIb

U.R.S.I.-UNESCO ACCOUNT FOR THE FISCAL YEAR 1955

Belgian francs

RECEIPTS

1) *Category* 2. *Meetings* :	
Subvention for meetings	125 500.—
Expenses for U.R.S.I./A.G.I. Committee Meeting ..	42 411.—
	83 089.—
2) *Category* 4. *Publications* :	
Subvention for publications	351 400.—
	434 489.—
Exceeding the subvention, to be supported by U.R.S.I.	49 238.10
	483 727.10

Remarks :

1. As it will be indicated in the Activities Report, U.R.S.I. supported organizational expenses of F. B. 17 336.— for U.R.S.I./A.G.I. Committee Meeting.
2. U.R.S.I. organized a meeting of its Ursigram Committee. The expenses were supported by U.R.S.I. and amounted to F. B. 13 337.65.

EXPENSES

1) *Category* 2. *Meetings* :		
U.R.S.I./A.G.I. Committee Meeting :		
a) Travel expenses	16 611.—	
b) Subsistence expenses	25 800.—	
		42 411.—
2) *Category* 4. *Publications* :		
a) Preparation	45 750.—	
b) Printing	410 764.60	
c) Postage	27 212.50	
		483 727.10
		526 138.10

Appendix IIc

U.R.S.I.-UNESCO ACCOUNT FOR THE FISCAL YEAR 1956

			Belgian francs
	RECEIPTS		
Subvention :			
a) for meetings ($ 2 500)		125 000.—	
balance transferred under « Publications » :	125 000.—		
	81 947.—(1)		
		43 053.—	
			81 947.—
b) for publications ($ 4 500)		225 000.—	
from Meetings account		43 053.—	
			268 053.—
			350 000.—
Balance transferred to U.R.S.I. account			182 521.—
			532 521.—
	EXPENSES		
A) MEETINGS :			
U.R.S.I./A.G.I. Committee Meeting :			
1) Travel expenses		29 960.—	
2) Subsistence expenses		35 350.—	
3) Organizational expenses		16 637.—	
			81 947.—(1)
B) PUBLICATIONS :			
1) Printing		394 337.30	
2) Postage		26 670.70	
5) Duplication, designs, translations, stationery		29 566.—	
			450 574.—
			532 521.—

Appendix III

PUBLICATIONS ACCOUNT 1954-1956

Belgian francs

(January 1, 1954 — October 31, 1954 — 10 months)		
1. Preparation	18 632.—	
2. Printing	200 630.—	
3. Postage	13 093.60	
		232 355.60
4. Expenses supported by U.R.S.I.		5 575.—
		237 930.60
(November 1, 1954 — October 31, 1955)		
1. Preparation	54 750.—	
2. Printing	410 764.60	
3. Postage	27 212.50	
		483 727.10
(November 1, 1955 — October 31, 1956)		
1. Preparation	29 566.—	
2. Printing	394 337.30	
3. Postage	26 670.70	
		450 574.—
Expenses for Publications 1954-5-6. Total		1 172 231.70
Unesco Subvention for publications :		
1954	118 407.90	
1955	434 489.—	
1956	268 053.—	
		820 949.90
		351 281.80

Difference supported by U.R.S.I. :	
cfr. : Appendix I*a*	119 522.70
Appendix I*b*	49 238.10
Appendix I*c*	182 521.—
	351 281.80

Appendix IV

ACCOUNT OF THE XIth GENERAL ASSEMBLY (THE HAGUE, 1954)

Belgian francs

Receipts		
Unesco Grant	98 625.22	
From reserve for General Assemblies and Meetings	145 740.24	
		244 365.46
Expenses		
Transportation and subsistence	117 766.01	
Organizational expenses	8 393.58	
Preparation of documents	102 069.00	
Sub-Commission IIIc Meeting	5 314.40	
Loss by change	1 872.06	
Reception expenses	8 950.41	
		244 365.46

Appendix V

GENERAL FINANCIAL STATEMENT OF U.R.S.I. ACCOUNTS

1954 (10 months)

Receipts	Belgian francs	Expenses	Belgian francs
Unesco grants	217.000	Publications (total)	238.000
Subscriptions	552.000	Meetings (total)	249.000
Miscellaneous	54.000	General Secretariat	238.000
		General Administration and miscellaneous	4.000
		Balance in hand	94.000
	823.000		823.000

1954-1955

Receipts	Belgian francs	Expenses	Belgian francs
Unesco Grants	477.000	Publications (total)	484.000
Subscriptions	777.000	Meetings (total)	74.000
Miscellaneous	50.000	General Secretariat	306.000
		General Administration and miscellaneous	22.000
		Balance in hand	418.000
	1.304.000		1.304.000

1955-1956

Receipts	Belgian francs	Expenses	Belgian francs
Unesco Grants	350.000	Publications (total)	451.000
Subscriptions	695.000	Meetings (total)	90.000
Miscellaneous	76.000	General Secretariat	332.000
		General Administration and miscellaneous	13.000
		Balance in hand	235.000
	1.121.000		1.121.000

Appendix VI

PROVIDEND FUND

Budget revised by the Bureau (March 1958)

1957-1960

	Belgian francs
First instalment from balance in hand 1956	292 220.—
Annual instalment from budget, 3 years period	150 000.—
	442 220.—
Annually deduction from Fund (3)	300 000.—
Balance in hand in 1960	142 000.—

Appendix VII

NEW REGULATION FOR TRAVEL AND SUBSISTENCE

The following rules were adopted at the XIIth General Assembly of U.R.S.I. :

A. — *Travelling Expenses*

Travelling expenses will be reimbursed, in the currency in which the tickets were bought, against a claim made on the form drafted by the Secretary General.

Travel is permissible at the following rates :

Rail : Ordinary first class seats or sleepers.

Air : Normally at tourist rates. First class rates are permissible whenever an overnight journey is involved.

Sea : At a rate not exceeding the first class air fare.

B. — *Subsistence Allowances*

Subsistence allowances will be paid at the place of meeting at the following rates :

Standard rate : The standard rate is 15 dollars for each night spent at the place of meeting.

Special rates : For Canada, U. S. A., U. S. S. R., France (Paris) and Japan, the rate is 18 dollars a night.

Rates en route : The following additional per diem expenses may be claimed, for reimbursement together with the travelling expenses :

6 *dollars* per 24 hour period spent on a train.

3 *dollars* per 24 hour period spent on board ship or aircraft.

Appendix VIII

BUDGETARY ESTIMATES FOR THE FISCAL YEARS 1957-58 AND THE FOLLOWING (1)

Belgian francs

Receipts

Subscriptions	1 000 000
Sale of publications	40 000
Bank interests	25 000
	1 065 000

Expenditures

1. Salaries and honoraria	350 000
2. Social laws	15 000
3. Stationery	13 000
4. Postages, Telephone	17 000
5. Rent, Heating, cleaning, fire insurance	50 000
6. Furniture, insurance	15 000
7. Travelling expenses	10 000
8. Entertainment	10 000
9. Allowance to Commission Chairmen	10 000
10. General Assemblies and Meetings	300 000
11. Publications	150 000
12. Subscription to I.C.S.U.	20 000
13. Providend fund	70 000
14. Available	35 000
	1 065 000

(1) Due to the change of location and to the increase of the General Secretariat staff, the Board of Officers decided in March 1958, to bring the following changes to the estimates :

1. Salaries	375 000
2. Social laws	20 000
5. Rent heating, cleaning, etc.	65 000
13. Providend fund	50 000
14. Available at the disposal of the Secretary General	10 000

Ursigrams

1. Historical survey.
2. Report of the Chairman of the Permanent Committee on Ursigrams.
3. Meeting, August 30th, 1957.
4. Recommendations submitted to the Executive Board of U.R.S.I.

1. — Historical Survey on Ursigrams

The International Geophysical Year having demonstrated, in a more evident manner, the services yielded by Ursigrams to sciences related more particularly to the activities of U.R.S.I., it seems useful to give here some details on the origin of the Ursigrams as well as on the origin of the Permanent Ursigram Committee.

The following is quoted from a paper published in *L'Onde Electrique* (in December 1931, Vol. 10, N° 120) under the title « Scheme of Ursigram emissions made by the French broadcasting stations under the auspices of the French Committee of Scientific Radiotelegraphy, to be applied from January 1st, 1931 » :

« The emissions concerned will replace the geophysical bulletins, transmitted up to now in clear by the radiotelegraphy stations of Bordeaux and Pontoise and by the radio telephony station of the Eiffel Tower.

The Eiffel Tower station (radio telephony) will continue to broadcast in clear, on 1445 m wave-length, the geophysical and astrophysical bulletin.

Besides the Ursigram emission, the stations of Lafayette (radio telegraphy) on 18900 m, and the station of Pontoise (radio telegraphy) on 28.50 m, will broadcast daily a group of letters for propagation studies purposes.

The programme of these emissions will be the following :

20.06 GMT, end of time-signal broadcasting.

20.10 to 20.15 GMT, signals for propagation studies. Emission of the letter E followed by a group of control letters.

20.15 GMT, Ursigrams.

The Ursigrams sent by the stations of Lafayette and Pontoise will contain :

1° a very condensed meteorological bulletin, established by the National Meteorological Office.

2° a geophysical bulletin, giving information on the Earth's magnetic field and on atmospheric electricity, established by the Geophysical Institute of Paris after observations made at the Val Joyeux Observatory (Seine et Oise).

3° an astrophysical bulletin on solar activity, as deduced from observations of sunspots, prominences, filaments (prominences seen projected on the disk), and faculae. This bulletin will be established after observations made at the Meudon Observatory.

4° a bulletin giving the source-centres of atmospherics, established after observations made daily at 13.00 by the Radio Research Station at Slough (England). This bulletin will be sent once a week (in principle each Monday) and will give centres observed during the preceding week.

5° a bulletin indicating for a given frequency, the height of the Kennelly-Heaviside layer after measurements by Prof. Appleton and transmitted by the British National Committee.

The general scheme of Ursigrams will be the following :

URSI URSI URSI

BAR

Text of meteorological bulletin

MAG

Text of magnetic bulletin

ELC

Text of the bulletin on atmospheric electricity

SOL

Text of the bulletin on solar phenomena

ATS

Text of the bulletin on atmospherics

KHL

Text of the bulletin on the Kennelly-Heaviside layer's height

(These informations were followed by codes concerned with each bulletin).

The usefulness of Ursigrams was rapidly recognized, and in a few years the example given by the French National Committee was followed by the National Committees of the United States, of Japan and of Italy. Unfortunately the codes used by the various countries were not the same.

During the General Assembly in Venice in 1938, the delegates of countries broadcasting Ursigrams agreed that the messages sent by the four countries were not very different in form, and that it should be easy to reach an agreement in view of setting up an international code. For this reason, the Commission IV (Liaison with operators, practitioners, amateurs, and related sciences) proposed to the General Assembly the appointment of a Sub-Commission in order to draft a unified code for Ursigrams, and to study how to improve and extend their use (U.R.S.I., Vol. V, fasc. 2, pp. 35-37). These proposals were accepted by the General Assembly. Unfortunately, the World War put an end to the Sub-Commission activity.

During the General Assembly of Paris, Commission II (Radio Propagation) suggested the appointment of a Sub-Committee to consider matters related to Ursigrams. In 1950, in Zurich, on a proposal made by Commission III (Ionosphere and Wave Propagation), the Permanent Committee of Ursigrams was established, which is still functioning under the chairmanship of Father P. Lejay. The activities of this Committee since this epoch have been summarized in the Proceedings of the General Assemblies, in the *U.R.S.I. Information Bulletin*, and in the following Report.

2. — Report of the President of the Permanent Committee on Ursigrams (Doc. nº 306)

Translation

The Ursigram Committee Report to the General Assembly of The Hague (1954) emphasized the extension taken at this time by the interchange service of ionospheric, geophysical and solar

informations. The importance of these interchanges has but increased since that time, owing to a greater number of participating observatories and to the increasing quantity of information requested by users.

The Ursigram Committee was faced with a new task, with the creation by C.S.A.G.I. of a service for predicting Alerts and Special World Intervals located in Boulder Laboratories.

The problem to solve was to provide this service with *all the observations needed*, without disturbing the normal interchange of data and, as far as possible, in avoiding redundances and a multiplication of different codes.

The Committee met in Bagneux on September 19-21, 1955. Some astronomers were invited to participate as consultants. Divergencies between observational methods of the chromosphere and the corona were emphasized in relation with a drafting of codes which should satisfy at the same time forecasters and scientists. Mr. Shapley proposed to prepare a project of codes, to be submitted to European and Japanese representatives. These codes, completed in October 1955 were referred for examination to specialists participating in I.G.Y. operations. The European delegates met later, also in Bagneux, on February 22-24, 1956 ; it was decided to maintain provisionally the European Codes with slight modifications. However, informations to United States were transmitted henceforth by NERA and Darmstadt in « interchange » codes, at the price of a supplementary work of translation from informations received in European codes as broadcasted by Pontoise and Hamburg.

It was then found obvious that it would be impossible to satisfy all users in maintaining a unique code for each discipline. New codes were drafted with the aim of bringing to an essential unification, convenient variants adapted to the possibilities of observatories and to the needs of users.

These codes were published in the Draft Manual for I.G.Y., and used since January 1957 by West Germany, Netherlands, U. S. S. R. and Japan for their transmissions to U. S. A. Various improvements to be applied from June 1st, 1957, were brought, and published in the Supplement to the Draft Manual.

In addition, a meeting of the European Committee of Ursigrams was held in Bagneux on June 13-15, 1957, at the occasion of various

I.G.Y. meetings. Important decisions were taken, and will be published in the *U.R.S.I. Information Bulletin.*

A decisive step has been reached with the general approval. Some improvements should be brought (with respect to geomagnetic data) which could not be definitively established, until the General Assembly of U.G.G.I. in Toronto. Likewise, the unceasing development of radioastronomical instruments for solar flux density measurements and localization of solar radiosources will imply, during the I.G.Y., new improvements to transmitted data.

The major decision reached were the following :

(1) Improvement of the geomagnetic code. Drafting of a new code UMAGO, very similar to the interchange code UMAGA, which should replace the European code MAGNE.

(2) Provisional maintenance of the European code CORAY for cosmic ray data (message not included in intercentre transmissions).

(3) Modification of the intercentre-code USIDA which replaces the European code PERTU.

(4) Maintenance of the European code ESFRE for sporadic-E data, but exclusion of this code from Pontoise and Ste-Assise broadcasts.

(5) Adoption of an abbreviated code FOFDE in replacement of the European code FODEU and of the intercentre code ION.

(6) Adoption of a new code (AURaa) for aurorae, according to a proposal from Sweden.

(7) Adoption of a new code CHRAG, in replacement of the European code CHROM for the solar chromosphere.

(8) Adoption of the interchange code UFLAR for flare data.

(9) Adoption of a new code RADIA, in replacement of the European code SOLER ; this new code might be a variant of the interchange code URAN (A, E, I), for radiosolar observations.

(10) Adoption of the interchange code UCORA for coronal data, the European code CORON being kept for detailed transmissions to Meudon Observatory.

The official members of the Permanent Ursigram Committee are :

Chairman : Father P. LEJAY.

Members : Colonel E. HERBAYS, Secretary General of U.R.S.I.,
A. H. SHAPLEY (U. S. A.),
Y. UYEDA (Japan).

This Permanent Committee asked, during the meeting in Bagneux in September 1955, to include the following representatives in its membership :

Dr. B. BECKMANN (West Germany),
A. H. DE VOOGT (Netherlands),
Mr. W. MENZEL (U. I. T.) (as consultant).

Moreover, it was proposed to appoint as Member Dr. S. Gejer, who would represent Sweden.

In the appendix, submitted for information, the list of data broadcasted by Pontoise and Ste-Assise will be found. Similar Ursigram data broadcasted by other stations will be published later.

Bagneux, July 1957.

P. LEJAY (*Chairman*),

(dated July 1957)

APPENDIX

RADIO TELEGRAPHIC BROADCASTING OF URSIGRAMS BY PONTOISE AND STE ASSISE

Information broadcasted

No change has been made from 1954 for what concerns time of emission and wave-length :

— The first broadcasting (« noon ») is made from 12.08 to 13.08 UT,

— The second broadcasting (« evening ») is made from 20.08 to 21.08 UT.

Each transmission mentioned above is made on a kilometre wavelength as well as on a decametre one, depending on the time.

For the present the « noon »-transmission on a day « D » includes in principle the following :

Spanish observations :

— Chromospheric and magnetic observations of the preceding day when the message from the observatory has not reached the

transmitting station on the day « D » (see below : « evening »-transmission).

French observations :

— Chromospheric observations from Meudon (CHROM) in the morning.

— Coronal observations at Pic du Midi-Observatory (CORON) in the morning (if conditions are good).

Netherlands observations : The 1954-report mentioned SOLER and FODEU messages from Netherlands. Since January 1957 such observations are no more broadcasted by Pontoise at noon. First, the solar noise observations are drafted in USIDA codes by NERA ; they reach France too late for a noon transmission. Secondly, the *fo*F2 observations being drafted in IONNE code with a *doubled* lenght, it was decided to suppress their transmission (24 groups in place of 12 in FODEU code).

Italian observations :

— Solar observations from Arcetri USSPE or from Rome USSPA in the morning ; geomagnetic observations of Monte Capellino MAGNE (day « D-1 »).

Japanese observations transmitted by The Hague :

— Magnetic observations MAGNE (D-1) from 00 to 24 h. UT.

— Solar radio noise SOLER (D-1) in URANA code from June 1st, 1957.

— Cosmic rays observations CORAY (Japanese code) (D-1) from 00 to 24 h. UT.

— Solar surface and chromosphere observations USSPE (D-1).

— Solar flares UFLAR (D-1), sometimes D from 00 to 02 h. UT.

Observations from Morocco (now by Telex network) :

— Critical frequencies of F2 by FODEU ;

— Critical frequencies of sporadic E by ESFRE ;

— Ionospheric disturbances by PERTU.

— Geomagnetic observations by MAGNE. These messages, refer generally to D-1 from 00 to 24 h. UT, or to D from 00 to 08 UT.

Czechoslovakian observations :

— Solar observations USSPE from Ondrejov near Prague ;

— Magnetic observations MAGNE from Pruhonice ;

— Solar noise observations URANA for variable periods (D-1 or D-morning).

U. S. S. R. observations :

— Solar observations USSPA and UFLAR ;

— Magnetic observations UMAGA, radio noise observations URANA ;

— Ionospheric disturbances USIDA, from various observatories, on variable periods (D-1 or sometimes D-2).

U. S. A. observations :

— Chromospheric observations UFLAR from various observatories ;

— Magnetic observations UMAGA (D-1 from 03 to 24 h. UT, D from 00 to 03 h. UT) ;

— Radio solar observations URANA, URANI, URANO on variable periods (D-1, D-2 and even D-3) ;

— Ionospheric disturbances USIDA on variable periods ;

— Coronal observations UCORA, periods similar to those of URANA, URANI, URANO.

The « evening » transmission on a day « D » includes in principle following :

— Solar observations CHROM and CORON from France (not transmitted at noon).

— Solar observations USSPE, UFLAR (Florence), USSPA, UFLAR (Rome), USSPE, UFLAR (Ondrejov) (if not transmitted at noon).

— Solar observations CHROM, CORON, from Germany and Austria D, D-1, D-2.

— Solar observations USSPO, UFLAR of Tortosa (when accessible).

— Solar observations UFLAR from Capri-Swedish, and from observatories of Herstmonceux, Dublin, Uccle.

— Ionospheric observations FODEU, ESFRE (Lindau, Germany) : D, D-1, D-2 on mondays and similar days in Germany.

— Magnetic observations MAGNE (Germany, Spain, France, Italy, Sahara : D-1 ; Wingst, Tortosa, Chambon-la-Forêt, Monte Capellino, Tamanrasset : D from 00 to 06 UT).

— Radioelectric propagation PROPA — 5 paths studied from Germany ; 3 paths in 1954 : D, D-1, D-2.

— Eventually, cosmic radiation CORAY (Germany).

— Ionospheric disturbances PERTU, observed on the same day in any european station mentioned.

— Solar noise observations URANA, URANI, URANO, URANY (Nera : D), URANY (Nançay).

— Japanese observations transmitted by The Hague, when not accessible on the morning for noon transmission.

Bagneux, July 1957.

ADDENDUM

From July 1957, other transmissions are regularly made :

Spain : USSPO, MAGNE, UMAGA, UPATA, URANA, CORAY.

France : CHRAG, MAGNE.

Netherlands : USIDA, UMAGI, UMAGA, UFLAR.

Belgium : (Uccle and Humain) : USSPA, CHROM, CHRAG, UPATA, UFLAR, URANA.

Czechoslovakia : CORAY, UPATA, UFLAR, USIDA.

U. S. A. : MAGNE.

Sweden : AUR.

New Delhi : UPATA, USIDA, UFLAR.

This list is not exhaustive.

Brussels, February 1958.

3. — Meeting held on August 30th, 1957

Were present : the Members of the Permanent Committee on Ursigrams and those of the European Sub-Committee, at that time in Boulder.

At this meeting, the situation of the Ursigram Committee was reviewed.

The Ursigrams were created as a result of the needs resulting from strong correlations between solar, geophysical (particularly geomagnetic), and ionospheric phenomena. Ursigrams are transmitted not only to be used by ionospheric forecasters, but also by astronomers and geophysicists who are sometimes working in isolated observatories.

Numerous phenomena observed by specialists in various fields must be followed from day to day ; on the contrary, for most disciplines, publication of data is only made (and could not be made otherwise) after long delays. An immediate transmission of data is needed not only for radiophysicists who should be warned on solar and geophysical phenomena for propagation forecastings, but also for scientists of other disciplines who must be informed on the evolution on a worldwide scale of observed phenomena. At a time when ionosphere was only but suspected, and when radioelectricity was but a transmitting agent, Ursigrams were primarily created for scientists of other disciplines and particularly for astronomers and geomagneticians. Ionospheric data, added later, form now an important part of the Ursigrams. This part is fundamental for forecasting services but also of primary importance for geophysicists in general.

Ursigrams are now more than twenty five years old ; the participating observatories became more and more numerous, as well as the concerned disciplines. These messages are now of primary importance to numerous workers ; they are taking an increasing interest with the development of our knowledge on correlations, and with the increasing number of specialists who must place their observations in the framework of studies made by other observatories.

The present co-operation of specialists pertaining to other Unions (IAU, UGGI) shows obviously how U.R.S.I. initiative has been appreciated. This co-operation has become, if possible, even more efficient and appreciated during the preparation of the I.G.Y.

It should now be considered, in the present situation, how this organization should be strengthened in order to become more adapted to the needs of users.

As U.R.S.I. took this initiative, it seems not advisable that this Union renounce to the responsabilities implied by this service, not withstanding the advantages that other Unions might find in this respect.

To conciliate these various interests, the following organization is proposed which seems to preserve the U.R.S.I. position and to give satisfaction to other Unions from which information comes.

This organization should consist in :

(*a*) *Regional Committees*, the members of which are designated by the National Committees of countries participating in the Ursigrams network. The Regional Committees should include specialists of various disciplines. They are under the chairmanship of a President, elected by the corresponding Regional Committee. The Central Committee is composed of the Presidents of the Regional Committees.

(*b*) A *Central Committee*, composed of members nominated by the Regional Committees (four members representing respectively America, Europe, Eurasia, Far-East) and of the Secretary General of U.R.S.I.

(*c*) The *Board of Trustees* of the Permanent service, composed of two Members by Union concerned (U.R.S.I., I.A.U., U.G.G.I.) in addition of FAGS representatives ; the two U.R.S.I.-members are designated by the Executive Committee of U.R.S.I., on proposal of the Central Committee.

Role of the Committee

Regional Committees take all steps in view of : *collecting* all data obtained from scientific institutions of the concerned region, *insuring* a wide diffusion to users of these data inside the region, *drafting* the summary of data needed by other regions, and *transmitting* this summary in a convenient form.

The *Central Committee* takes care of the coordination between Regional Committees and of the good working of interchanges between regions. This committee accounts for general activity to U.R.S.I. and to the Board of Trustees of the Ursigram Permanent Service, it is responsible for execution of decisions taken by the Board of Trustees of the Permanent Service.

Such an organization, if it were accepted, would be advantageous in maintaining the responsability of U.R.S.I. and in giving place to other Unions in two ways :

(*a*) by their representation in the Board of Trustees,

(*b*) by the presence in Regional Committees, of specialists of various disciplines nominated by National Committees.

On the other hand, Ursigrams should take profit of advices from qualified persons. Without representatives of interested Unions, on the contrary, it will be difficult to take a sufficient account of international decisions adopted by the Unions in all disciplines concerned with Ursigrams.

Practically, the Executive Committee of U.R.S.I. should :

(*a*) recognize the Federation of Permanent Services (whose By-Laws are already approved by U.G.G.I. and I.A.U.).

(*b*) designate two members of the Board of Trustees of FAGS.

(*c*) designate two members of the Board of Trustees of the Ursigram Permanent Service.

(*d*) invite the National Committees of U.R.S.I., for countries participating in the Ursigrams network, to designate their delegates to a Regional Committee at their own choice.

(*e*) invite the Secretary General to keep other interested Unions and FAGS informed of these decisions.

After discussion of this report, it was decided to establish under the chairmanship of Mr. A. H. Shapley, a Working Group with the aim of drafting a Resolution for the U.R.S.I. Executive Committee.

This Working Group made the following Recommendations :

4. — Recommendations submitted to the Executive Committee of U.R.S.I.

1. The Committee proposes that it be re-constituted into a Central Committee composed of Members designated by region committees of Ursigrams and the U.R.S.I. General Secretary. For the present there are four such regions (Western Hemisphere, Europe, Eurasia, Far-East). Until any designation are made in this manner, the members shall be MM. Lejay, Uyeda, Shapley, Pushkov and the U.R.S.I. General Secretary. The Regional

Committees are to be formed by members designated by National Committees of U.R.S.I., of countries participating in the Ursigram network. The details of this new committee structure will be formulated later by the Central Committee.

2. The Committee has discussed briefly the questions put to it by the U.R.S.I. Executive Committee on the subject of a proposed Permanent Service on Ursigrams associated with FAGS. The concept of such a permanent service is approved in principal. Since there has been insufficient time to discuss the details of the organization and functioning of such a permanent service, it is proposed that the Central Committee be instructed to continue their discussions and to present their recommendations to the U.R.S.I. Board of Officers for action so that the work may proceed at an effective level after the end of the I.G.Y.

* * *

In its session on September 4, 1957, the Executive Committee agreed with these recommendations and invited the Central Committee of Ursigrams (CCU) :

(i) to undertake its re-constitution and pursue its activities along the lines given in Recommendation 1 ;

(ii) to continue the discussions on the adherence to FAGS of a Permanent Service on Ursigrams ;

(iii) to report on (i) and (ii) to the Board of Officers for action.

* * *

On the other hand resolution 2 of Commission V, which was adopted by the General Assembly, reads as follows :

« A member of Commission V should be appointed to the Ursigram Permanent Committee. » In accordance to I, (i) this appointment is left to the choice of the CCU.

U. R. S. I.
and the International Geophysical Year

U.R.S.I.-A.G.I. Committee :

Summary report on the activity of the Committee.
Report on Boulder meetings.
Recommendation.

Report on Meeting on the I.G.Y. held 27th August, 1957 :

Morning session :

1. Introductory remarks : Sir Edward V. Appleton, Chairman U.R.S.I.-A.G.I. Committee.
2. Dr. L. V. Berkner, Vice-President, Comité Spécial de l'Année Géophysique Internationale (C.S.A.G.I.).
3. Status of I.G.Y. Programme : Dr. M. Nicolet, Secretary General, C.S.A.G.I.
4. Final Station Networks : Summary Status Reports :
   - 4.1 Ionospheric Vertical Soundings : A. H. Shapley.
   - 4.2 Absorption Measurements : W. J. G. Beynon.
   - 4.3 Ionospheric Drifts : J. A. Ratcliffe.
   - 4.4 Atmospheric Noise : F. Horner.
   - 4.5 Whistlers : M. G. Morgan.
   - 4.6 Radar Aurora : A. C. B. Lovell.
   - 4.7 Meteors : A. C. B. Lovell.
   - 4.8 Backscatter Soundings : A. M. Peterson.
   - 4.9 Airglow : F. E. Roach.
   - 4.10 Status of I.G.Y. Data and Analysis Centres : P. Mange.
   - 4.11 World Day Programme and Short Term Data Interchange : A. H. Shapley.
   - 4.12 Ursigrams : Father P. Lejay.
   - 41.3 Rocket and Satellites during the I.G.Y. : L. V. Berkner.

U.R.S.I.-A.G.I. Committee

Summary Report on Activities of the U.R.S.I.-A.G.I. Committee since XIth General Assembly of U.R.S.I.

During the period under review, two meetings of the Committee have been held. Full reports of these have been published in the *U.R.S.I. Information Bulletin*, N° 94, pp. 24-41 and N° 99, pp. 30-48. The principal matters discussed are briefly indicated below.

Meeting at Brussels 8-10th September 1955

The meeting was attended by 8 members and 18 observers. Two main working parties were established. The first considered the world distribution of I.G.Y. ionospheric stations and formulated proposals for filling gaps in the world network. The second working party considered procedure for the uniform scaling of *h'f* records, the interchange of data and the publication of ionospheric characteristics during the I.G.Y.

At this meeting the Committee made arrangements for the production of a series of instruction manuals covering all the principal I.G.Y. ionospheric studies and also formulated proposals concerning the collection, publication, circulation etc... of I.G.Y. ionospheric characteristics.

Meeting at Brussels 29-31 August 1956

On this occasion 9 members and 23 observers attended. Satisfactory progress was reported with the preparation of the I.G.Y. Instruction Manuals, with the preparation of a detailed comprehensive list of ionospheric stations and with the compilation of tables of solar zenith angles for I.G.Y. ionospheric stations.

Working parties were appointed to discuss various aspects of the I.G.Y. ionospheric programme and reports were prepared covering measurements of absorption, drifts and the observation of whistlers. Further discussions also took place on the 1955 proposals for the establishment of I.G.Y. Regional Data Centres. A Sub-Committee on vertical ionospheric soundings presented a very comprehensive report on various aspects of this subject including sounding schedules.

During the I.G.Y., scaling procedures and a revised list of symbols for use in the reduction of ionograms.

It is expected that the Committee will meet again during the forthcoming U.R.S.I. Assembly at Boulder, U. S. A.

W. J. G. Beynon,

Report on Meetings of the U.R.S.I.-A.G.I. Committee

Two meetings of the U.R.S.I.-A.G.I. Committee were held at Boulder (on 29th August and 3rd September, 1957) under the chairmanship of Sir Edward Appleton, Chairman of the Committee.

1. — Publication

(i) *Publications concerned with I.G.Y. Radio Studies*

(see also minute 3 below)

The Committee agreed that a policy of undirected publication of I.G.Y. results should be encouraged. It would appear that publication of I.G.Y. radio studies could be considered in three categories :

(*a*) *The planning activities* : these were contained in the reports on the proceedings of the U.R.S.I.-A.G.I. Committee and had been published in the *U.R.S.I. Information Bulletin*. It was agreed that, for record purposes, these might be reprinted in the appropriate volume of the C.S.A.G.I. Annals of the I.G.Y.

(*b*) *Publication of volumes of selected ionospheric data* : The Committee noted that a preliminary proposal for printing about three volumes of basic ionospheric data had been made by the C.S.A.G.I. Working Group of Ionospheric Data Centres and agreed to endorse this proposal.

(*c*) *Publication of « Interpretative Volumes »* : The Committee agreed to sponsor the preparation by suitable authors, within a period of about three years after the conclusion of the I.G.Y. of volumes of an interpretative character in which a connected survey might be given of published I.G.Y. results in the radio field.

(ii) *Bibliography of I.G.Y. Radio Publications*

The Committee discussed the question of U.R.S.I. preparing and publishing a Bibliography of I.G.Y. Radio Publications but

it was felt that this would be adequately covered by the C.S.A.G.I. Publications Committee and no further action was taken.

(iii) *Report on I.G.Y. Day Meetings during the U.R.S.I. Assembly*

The Chairman reported on the great success of the meeting on the I.G.Y. held at Boulder on 27th August and the Committee agreed to recommend to the Executive Committee that the morning proceedings of this meeting be published in the Proceedings of the XIIth General Assembly.

2. — U.R.S.I. World-Wide Vertical Soundings Sub-Committee

The Chairman of this Committee (Mr. A. H. Shapley) reported on the recent activities of this Sub-Committee. It was stressed that during the I.G.Y. in order to safeguard the homogeneity of ionospheric data, it is essential for the World Wide Soundings Committee to maintain direct contact with operating stations and it was agreed for the duration of the I.G.Y. National Committees should be urged to permit such direct contact.

It was brought to the notice of the Committee that certain I.G.Y. ionospheric stations are not operating according to the agreed plan and the U.R.S.I.-A.G.I. Committee agreed, as a matter of urgency, to call the attention of National Committees to the need for ensuring that all stations are placed in full operation as soon as possible.

It was agreed that the World-Wide Soundings Sub-Committee should continue in being until the reconstitution of U.R.S.I. Sub-Commission III*a*, probably at the next U.R.S.I. Assembly. It was further agreed that the membership of the Sub-Committee should consist of National Committee nominees, that powers of cooption should be given to the Chairman and that it should have an Executive Committee with the following membership : Shapley, Rawer, Aono, Piggott, Turner, Mednicova.

3. — Co-operation in certain I.G.Y. Ionospheric Studies

The question of U.R.S.I. support for groups of I.G.Y. workers wishing to co-operate in certain studies (e.g. ionospheric drift measurements) was discussed and it was agreed that the U.R.S.I.-A.G.I. Committee should encourage such co-operation. Furthermore, should any difficulties arise over the publication of the

results of such co-operative studies, then the Committee agreed to recommend that U.R.S.I. should publish these results in the form of an U.R.S.I. Special Report.

4. — U.R.S.I. Compendium of Ionospheric Stations

The Secretary reported on the present position of this volume and it was agreed that publication should be pressed forward as early as possible. It was suggested that at a later date, information on magnetic dip at altitudes of 100, 200 and 300 km should be included in the Compendium but that publication should not be delayed on this account.

5. — I.G.Y. Research Scholarships

The Committee discussed the possibility of Educational Trusts and Foundations establishing I.G.Y. Scholarships to enable workers to undertake the analysis of I.G.Y. data. The following recommendation was adopted by the Committee :

The U.R.S.I.-A.G.I. Committee is well aware of the plans already formulated in many institutions throughout the world for the scientific elucidation of I.G.Y. radio observations by way of theoretical study. Nevertheless, in view of the vast and unique opportunity for geophysical comprehension which such observations provide, the Committee invites all bodies which sponsor scientific research to consider the possibility of instituting special I.G.Y. Fellowships and Studentships — of all ranges of seniority, from professorial downwards — for the prosecution of such theoretical research in I.G.Y. World Data Centres, Universities and similar institutions on an individual or group basis.

The Committee warmly commends the action of Unesco in instituting special studentships for the operational phase of the I.G.Y., and trusts that the same body will continue to support individual scholars, in the same way, during the post-I.G.Y. stages of scientific elucidation.

6. — I.G.Y. Terminating Committee

The Committee received the I.C.S.U. proposals for establishing a Terminating Committee for the International Geophysical Year.

This Terminating Committee will come into being on the dissolution of the C.S.A.G.I. Secretariat in July 1959. The Committee agreed to recommend to the U.R.S.I. Executive Committee that Dr. W. J. G. Beynon be the U.R.S.I. representative on this Terminating Committee.

7. — Future of U.R.S.I.-A.G.I. Committee

It was agreed that the U.R.S.I.-A.G.I. Committee should continue in being to deal with all radio matters pertaining to I.G.Y. studies and the subsequent analysis of results. The next meeting will be held in 1958. The following revised membership was proposed and subsequently endorsed by the U.R.S.I. General Assembly :

Sir Edward Appleton (*Chairman*), Dr. L. V. Berkner (*Vice-Chairman*), Dr. H. G. Booker, Dr. N. Pushkov, Dr. Fukushima, Dr. W. Dieminger, Dr. R. L. Smith-Rose, Mr. J. A. Ratcliffe, Mr. A. H. Shapley, Dr. Slutz, Dr. D. F. Martyn, Dr. Nicolet, Father P. Lejay, Mr. D. Lepechinsky, Colonel E. Herbays, Dr. W. J. G. Beynon (*Secretary*).

In proposing this revised membership the Committee has in mind the future greater relative importance of the World Data Centres and accordingly the names marked with an asterisk are proposed as representatives of the four World Data Centres.

W. J. G. Beynon,
Secretary.

Recommendations to the General Assembly

Report on Meeting on the « International Geophysical Year » held on 27th August, 1957, during the XIIth General Assembly

MORNING SESSION

1. — Introductory Remarks by Sir Edward Appleton (Chairman, U.R.S.I.-I.G.Y. Committee)

If these opening remarks of mine were a sermon — which of course they are not — I should take as my text a sentence from Job, Chapter 12, verse 8, where we read the words « Speak to the earth

and it shall teach thee ». For, during this I.G.Y. meeting, you will hear about the scientific radio questions we have proposed to ask the earth and its atmosphere. We shall, in fact, be talking about both the questions we've formulated and *where* and *how* we're going to ask them.

Now I'm sure I am speaking for every member of the I.G.Y. Committee when I say how much we, the members of the U.R.S.I./ I.G.Y. Committee, welcome this opportunity of rendering an account of our stewardship to our parent body. It was exactly seven years ago that the Mixed Commission on the Ionosphere, meeting in Brussels during the period 4th to 6th September, 1950, formally proposed, in a reasoned report, that there should be a 3rd International Polar Year in 1957-58. However, although the proposal referred to a *Polar* Year, the report contained these words : « It should perhaps be explained that the expression « Polar Year » in this document implies not only a year in which special observations would be made in polar regions, but also one in which observers in all latitudes would co-operate to the maximum extent so as to to give as complete a picture as possible of world-wide geophysical phenomena. It is assumed that the Antarctic region would receive its full share of attention. » The report further recommended that I.C.S.U. should be invited to set up a co-ordinating committee to encourage, through the various Unions and their National Committees, the establishment of an appropriate network of observing stations. There was also a recommendation concerning the setting-up of an appropriate semi-permanent central secretariat.

Fortunately this formal proposal by the Mixed Commission commended itself to more influential bodies — to our own Radio Union for example — indeed U.R.S.I., through its own Ionospheric Commission, endorsed it at its Zurich meeting the very same month ; it appealed to its sister Unions ; and, most notably of all, to our parent body, the International Council of Scientific Unions. Quite appropriately, I think, our own Secretary-General, Colonel Herbays, was appointed the Secretary of the I.C.S.U. working group set up in 1952 to frame the programme of the I.G.Y. ; for by that time, to everyone's approval, it had been decided to make it a *Geophysical* Year and not only a *Polar* Year. This body held its first meeting in 1952, in Brussels in the office of the Secretary-General of U.R.S.I.

In the same year, 1952, at our own U.R.S.I. meeting in Sydney,

Australia, our own U.R.S.I./I.G.Y. Committee, already appointed in 1950, was definitively formed — Dr. Beynon being confirmed as its Secretary and myself as its Chairman. Now I've put Dr. Beynon's name first, and for a very good reason. For it is largely due to his selfless devotion — to his singleness of purpose — to his unsparing exertions over the last five years — that your Committee is able to render to you today such an impressive record of its work and achievements. I shall have occasion later to mention other important names — and especially that of Mr. Shapley — but I am sure that *he* would be the first to endorse my warm tribute to Dr. Beynon.

Now I've only a few words more to say about the history of overall I.G.Y. organisation. In 1953, in the same room in the Palais des Académies where the original formal proposals had been drafted by the Mixed Commission on the Ionosphere the Special Committee for the I.G.Y. held its first plenary meeting, there the responsibilities of the I.C.S.U. working group were assigned to a new body, C.S.A.G.I., the President and Vice-President of which were Professor Chapman and Rear-Admiral Berkner, respectively — the two scientists who were, in fact, responsible for raising the whole subject of an I.G.Y. in discussion at the original Ionospheric Commission meeting I've already mentioned. At the same time Dr. Nicolet was appointed head of the Secretariat set up (in Uccle) in Belgium. It is pleasant for us, today, to remember the radio-scientific interests of all these three gentlemen, and to welcome them as principal speakers in our discussion this morning.

Now when C.S.A.G.I. was founded, in 1953, Dr. Beynon, already our Secretary, was appointed a member of it, in the rôle of Reporter for Group Subject V, the Ionosphere. In this way the work of our own I.G.Y. Committee has been kept in step with the general C.S.A.G.I. programme. However, I should explain that our U.R.S.I./I.G.Y. programme, as we shall see illustrated in our discussions today, is not restricted to ionospheric observations; though such observations account for a very large part of it.

Now there is only one more matter of early I.G.Y. history that I want to recall this morning. And that is to remind you that, at our 1954 General Assembly in The Hague, and on the motion of our Commission III (Ionospheric Radio), U.R.S.I. adopted the following resolution :

« U.R.S.I. therefore draws attention to the fact that an extension of present isolated rocket observations, by means of instrument earth satellite vehicles, would allow the continuous monitoring of solar ultra-violet and X-radiation intensity and its effects on the ionosphere, particularly during solar flares, thereby greatly enhancing our scientific knowledge of the outer atmosphere. »

I was glad to see that Dr. Dellinger, in his valuable article on international co-operation in radio research, published in the Proceedings of the I.R.E. last year, reminded his readers of this early reference, by a scientific body, to the special value of earth-satellite projects. As is well-known, the U. S. undertaking of such an outstanding enterprise was announced by President Eisenhower, himself, in 1955 ; and we have since learned that Russia is organising similar methods of geophysical exploration during the I.G.Y.

So much, then, by way of preamble. I now turn to the actual planning of I.G.Y. work in the field of scientific radio. Here we may note that we are concerned with three things :

(*a*) the siting of radio-scientific stations ;

(*b*) the organisation of operating procedure, in advance of the I.G.Y. and ;

(*c*) the communication by radio of geophysical and other information, likely to influence procedure, during the period of the I.G.Y. itself.

All of these three subjects have been given close attention ; the first two by your I.G.Y. Committee, and the third by the Ursigram Committee of U.R.S.I. under the Chairmanship of our President, Father Lejay.

The I.G.Y. Committee has counted the encouragement of vertical incidence radio sounding of the ionosphere, throughout the world, as a major task. To that end it has lent its authority in supporting proposals by National Committees for the institution of *new* sounding stations, especially those that filled gaps in world coverage. Valuable work in this connection was done by a Sub-Committee we set up under the Chairmanship of Dr. Smith-Rose, in 1955.

On present information, as furnished by the register of these stations compiled by our Secretary-General, Colonel Herbays, as many as 167 vertical-incidence ionospheric stations are now in operation throughout the world, of which 33 are in Arctic, and 17

in Antarctic, regions. However, from the essential standpoint of the geophysical interpretation of the results, which will later accrue from this global exercise, we have counted homogeneity in such data as a prime desideratum. We have therefore sought to attain maximum accuracy, uniformity and regularity in the production and interpretation of ionograms. And here I should like specially to mention, and warmly commend to you, the work of our World-Wide Soundings Sub-Committee, appointed just two years ago, which has been responsible for regularising all procedure designed to attain those objectives. Under the Chairmanship of Mr. Shapley, this Sub-Committee has made a major contribution to ionospheric study, the influence of which will extend far beyond the I.G.Y. itself. I pick my words deliberatly when I can. I do not think I could possibly cite a finer example of international co-operation in the field of science.

As will be readily understood, this World-Wide Ionospheric Soundings Sub-Committee was faced, in the first instance, by the differences existing in ionogram practice in different parts of the world. The Sub-Committee therefore, wisely, sought the opinion of more than 100 ionospheric stations on debatable points. In connection with the admittedly difficult subject of the interpretation of high-latitude ionograms, it also had the benefit of the excellent work of a Special Group which had devoted all its attention to this very subject.

In formulating its final proposals, in advance of the I.G.Y., the Sub-Committee had to balance the desirable with the practicable. And the merit of their proposals has been recognised by their general adoption. However, with becoming modesty, the Sub-Committee recognises that it may not have been able to smooth out *all* difficulties in advance of the I.G.Y. ; and, on the suggestion of Mr. Shapley, I have authorised it to continue in being.

Now it was the need to ensure the widest circulation of the agreed procedure in both the production and interpretation of ionograms that, in the first instance, prompted your main Committee to suggest the idea of the preparation of I.G.Y., radio manuals. However, we felt that such manuals should contain far more than a bare list of instructions ; and should include, in addition, material likely to engage and hold the interest of operators in the basic science of their routine work.

As most of you will be already aware, these radio manuals have now been written and published under the general editorship of Dr. Beynon and Dr. Brown. They form Volume III of a series of I.G.Y., instruction manuals. (Volume III was, in fact the first I.G.Y., instruction volume to appear in print. It was published before the I.G.Y. started ; and, indeed, long before that, lithograph copies were in the hands of our radio stations). Part I of this Volume III deals with the subject of ionospheric soundings and covers the recommendations of Mr. Shapley's Sub-Committee. In addition, the Sub-Committee has sponsored the production of an Atlas of Ionograms, a valuable document which supplements, by a wealth of further examples, the precepts enunciated in the Sub-Committee's written report.

Now, as is well known, vertical ionospheric sounding was conducted during the 2nd International Polar Year of 1932/33 ; but the manual apparatus used was crude in comparison with the automatic equipment we possess today. Also, since the 2nd Polar Year, a whole variety of other methods of geophysical exploration by radio have been developed. The U.R.S.I./I.G.Y. Committee has therefore actively sought to encourage the adoption of these methods on a world-wide basis. As a result I may mention, for example, that as many as 75 stations are measuring ionospheric absorption during the I.G.Y. Other organised studies are to be made of ionospheric drift, atmospheric noise, « whistlers », meteors, forward-scatter, backward-scatter, and so on. To assist in the formulation of programmes, special pre-I.G.Y. experiments were conducted, on an international basis, on absorption and ionospheric drift.

In addition, I.G.Y. instruction manuals have been written, by specialist authors, on these subjects. They form Parts II, III and IV of the Volume III I have already mentioned ; and with Part I, dealing with vertical incidence sounding, form an outstanding contribution to radio-scientific literature. French and Russian translations have been arranged.

So far I have dealt only with the *operation* of radio-scientific stations. The communication of information, to these stations, by the Ursigram service will be dealt with, later on in the meeting, by Father Lejay.

2. — The International Geophysical Year by Dr L. V. Berkner, (Vice-President, C.S.A.G.I.)

Mr. President, members of U.R.S.I. and guests :

I speak this morning on behalf of Professor Chapman, the President of the C.S.A.G.I., who unfortunately could not be here today since I.G.Y. duties have called him away. It is my purpose, therefore, to discuss for him the general character of the I.G.Y. program and certain aspects of it that relate especially to the U.R.S.I.

During the I.G.Y. as scientists we are thinking of the earth as a planet. Since any one cannot readily see very much of the earth at any one time, the cooperation during the I.G.Y. permits many observers scattered over the earth's surface to synthesize their observations so that a description of terrestrial phenomena can be made on a planetary scale. To do this successfully requires that our observations be made in accordance with common standards. To this end various working groups of the C.S.A.G.I. have developed suitable standards wherever these are needed, and the agreed methods of measurements are being published in the many manuals of the I.G.Y. that are appearing in the first six volumes of the Annals of the I.G.Y. Advance drafts of these manuals have been circulated and the final drafts of several of them have appeared. All of the manuals should be available in final published form before the end of this year. A second requirement to permit us to describe phenomena of the earth on a planetary scale is simultaneity of measurement. Many observations will be made continuously. In addition, regular 10-day intervals near the time of the equinoxes and the soltices known as World Meteorological Intervals (WMI) have been agreed upon. But more complicated observations that can only be made more rarely when unusual geophysical events occur must also be made simultaneously over the earth. Therefore, during the I.G.Y. the scientists of the earth have agreed to make such observations on a calendar of three or four Regular World Days each month. Such special observations are being made when world-wide geophysical disturbances are predicted. To make these predictions solar observers send reports of solar activity to three centers at Washington, Paris, and Tokyo. After combining the data, the facts are sent to the Central Radio Propagation Laboratory at the National Bureau of Standards at Washing-

ton where the complete story on solar activity is evaluated. When active regions appear on the Sun, the Washington Warning Center sends out an international alert on the world-wide I.G.Y. communications network (AGIWARN) to warn geophysical observers everywhere that the Sun may erupt. If the activity increases, the Warning Center announces a Special World Day over AGIWARN so that observers can be on the job with the most complex equipment when the eruption occurs and will be ready to follow its subsequent development and reaction on the Earth.

In this matter of standards and simultaneity the U.R.S.I. and its I.G.Y. Committee have played a major part. Volume 3 and parts of other manuals were developed directly under U.R.S.I. supervision, and for this the I.G.Y. is especially indebted to Dr. W. J. G. Beynon. The whole matter of World Days and the simultaneity of measurements as well as the AGIWARN was planned under Dr. Alan H. Shapley, C.S.A.G.I. Reporter for World Days, with the intimate and untiring collaboration of many members of the U.R.S.I. Intimately connected with this plan has been the enlargement of the program of Ursigrams to which President Lejay and M. Lepechinsky have contributed so much.

The I.G.Y. is now under way. It opened spectacularly with a series of solar eruptions followed by large magnetic disturbances and coincidental aurorae on its opening day July 1, 1957. More than 40 stations of 12 nations have established their bases on the Antarctic and operations there are proceeding with full vigor. For the first time in the history of science weather maps for the whole Antarctic Continent are being produced. These typify the extent of cooperation among the collaborating nations. In the Arctic, stations on the ice floes have been manned by the U. S. and the U. S. S. R. to observe the geophysical phenomena at the Antarctic bases. Literally hundreds of stations surround these stations on the land masses adjacent to the Arctic Ocean to provide a network of geophysical stations in the Arctic regions. A great network of thousands of stations covers the whole earth and these have been described in many scientific papers .

The Unions have played a vital part in the planning of the I.G.Y. First of all, their representatives have worked incessantly as members of C.S.A.G.I. and as C.S.A.G.I. reporters in the planning of the I.G.Y. program. The work of U.R.S.I. typifies the collaboration

of unions in international research efforts of the I.G.Y. in its highest form. The U.R.S.I./I.G.Y. Committee was of inestimable value to the organization of the I.G.Y. We owe a deep debt to the Chairman, Sir Edward Appleton, for his wisdom and foresight in leading this Committee, and to the U.R.S.I. generally for sponsoring and financing it. The Secretary of the Committee, Dr. Beynon, is also the C.S.A.G.I. Reporter for Ionospheric Physics and in this post he was able, through the machinery of the U.R.S.I. Committee, to mobilize the whole forces of radio science on this subject. Volume 3 of the I.G.Y. manuals stands as a monument to this effort. Likewise, the U.R.S.I./I.G.Y. Committee played a major role in working out the plans for world days and for I.G.Y. communications. Its activities were of tremendous value to Dr. Shapley, Reporter for World Days, who has been a long time member of the U.R.S.I. and who was able to use the mechanisms of the U.R.S.I. organization to great advantage.

I think it is fair to say that the example of the role played by U.R.S.I. in the planning of the I.G.Y. might well be considered as the ideal example of the appropriate relationships between the Unions and the Special Committees of the I.C.S.U. in future efforts of this kind.

The work of the next year will be devoted primarily to the observation and collection of data in accordance with the I.G.Y. plan. The World Data Center will inevitably play an important part in the activities immediately ahead of us, since they represent centers of the collection of data for which we have so long planned. With the collection of these data will come the extensive efforts ahead to synthesize the data, to describe the phenomena of the earth in new and more complete ways, and to analyze these descriptions for their real meaning in the planetary sense.

In this effort the Unions must play the vital role. We all visualize that the Assemblies of the U.R.S.I., and of the other Unions, will deal intimately with the various planetary aspects of the I.G.Y. Moreover, there will be an opportunity for a variety of symposia on special subjects which the data of the I.G.Y. now opens for discussion. One can suppose that these symposia will lead to published volumes that will describe in detail the knowledge that has been acquired in each field and sub-field of I.G.Y. activity. In these the Unions and the Joint Commissions must assume the major

responsibility. I might add that the U.R.S.I. at this Assembly will doubtless begin to give serious consideration to the symposia that it hopes to hold in the ensuing triennium and to the means of financing these and joint symposia with other Unions that fall within the interests of the U.R.S.I. This will be a major job of planning for the U.R.S.I.

In conclusion I know that I speak on behalf of the whole of the I.G.Y. organization and of its collaborators when I express to you the thanks of scientists generally for the work of the U.R.S.I. and its members in planning its part of the I.G.Y. On the other hand, speaking for the U.R.S.I. we all owe a special debt of gratitude to the General Secretary of the I.G.Y., Professor Nicolet, for this untiring effort as the center of communications and of planning for this venture. One can only say that the success with which the I.G.Y. was planned, and is now proceeding, describes as in no other way the integrity of scientists of all nations in joining hands to make this study of the earth possible.

3. — Status of I.G.Y. Programme by Dr Nicolet, Secretary General C.S.A.G.I.

Dr. Nicolet gave a summary of his paper « The International Geophysical Year », *Nature*, Vol. 180, pp. 7-10, July 6, 1957.

4. — Final Stations networks. Summary Status report

4.1. — Ionospheric vertical soundings : A. H. Shapley.

(The text of this report has not been received).

4.2. — Ionospheric Absorption Measurements : Dr. W. J. G. Beynon (C.S.A.G.I. Reporter for the Ionosphere).

The vertical sounding of the ionosphere about which Mr. Shapley has been speaking is concerned with the measurement of the time delay of radio signals reflected at the ionosphere and with the variation of that time delay with the frequency of the radiated signals. In measurements of ionospheric absorption we are concerned with the attenuation of such signals during the process of reflection from the ionosphere or in other words with the *reflection cœfficient of the ionosphere.*

Two main methods now exist for the study of ionospheric absorp-

tion. In the first, a pulse transmitter is located on the ground and the amplitudes of the signals reflected by the ionosphere are measured. By comparing the amplitudes of signals successively reflected by the ionosphere, the reflection coefficient can be deduced. Alternatively, if the amplitude of the initial signal radiated by the radio transmitter is known, then a measurement of the amplitude of the first order echo signal is sufficient to give the reflection coefficient of the ionosphere.

A second method of measuring ionospheric absorption has been developed in the last few years in which extra-terrestrial sources of radio waves replace the ground based transmitter and the attenuation of these incoming signals during their passage through the ionosphere is studied.

I shall not go into the theory of ionospheric absorption — it will be sufficient to say that, in general, the main absorbing region of the ionosphere is located below the E region. In some circumstances the major ionospheric absorption may occur at higher levels in the ionosphere but more often the main absorption occurs below about 100 km. Hence, measurements of ionospheric absorption provide us with information on the physical characteristics of this lower part of the ionosphere.

On the occasion of the Second International Polar Year of 1932-33, there were no systematic measurements of the ionospheric absorption of radio waves. In the 25 years since 1932, routine studies of ionospheric absorption have been established at a number of stations and with the development of the cosmic noise method a new and complementary approach to the problem has become available. If we designate the two methods (i. e. that employing a terrestrial transmitter and that employing an extra terrestrial transmitter), respectively as method A1 and method A2, then during the I.G.Y. we can expect to have data from 60 A1 stations and 17 A2 stations. The geographical distribution of the stations shows that there are 4 or 5 regions from which we can expect a good sample of absorption results. In Africa, within the tropics there are about 9 stations which will use method A1 and there will be another concentrated group of A1 stations in Europe. The A2 method is particularly well suited for the study of the intense absorption which occurs in polar « black-outs » and there is a fair distribution of A2 stations in and around the auroral zone. A chain of such

stations is being established in Alaska and with those in Western Europe we can look forward to some interesting results on ionospheric absorption in these northern latitudes. It is hoped that the absorption measurements at the auroral latitude stations will yield complementary information to that obtained from geomagnetic and auroral studies on the incidence of corpuscular radiation. At temperate and equatorial latitudes the A2 method should be a powerful means of studying all the phases of Sudden Ionospheric Disturbances (S.I.D's). In some places we find both the A1 and A2 methods being used side by side or at neighbouring sites so that a study of the results obtained simultaneously by the two methods should yield some information on the relative magnitudes of the absorption taking place at different levels of the ionosphere.

The principal objectives of I.G.Y. ionospheric absorption measurements may be briefly summarised as follows :

1. To obtain data from many more stations so that some kind of world picture of ionospheric absorption may be formed.

2. To study the growth and decay of ionospheric absorption during Sudden Ionospheric Disturbances and Polar Black-outs.

3. To examine in greater detail certain anomalies such as the peculiar increase in absorption observed in temperate latitudes during the local winter.

4.3. Horizontal Movements in the Ionosphere : Mr. J. A. Ratcliffe.

Horizontal movements in the ionosphere can be detected by radio methods only because horizontal irregularities occur in the ionosphere. These take one or other of the following forms :

(*a*) ionised meteor trails ;

(*b*) ionised auroral irregularities ;

(*c*) random patches of greater or smaller electron density ;

(*d*) wave-like « ripples » in the stratification of the electrons.

Measurements of horizontal movements are being made during the I.G.Y. by observing radio waves which carry evidence of one or other of these irregularities.

Radar-type apparatus is used to investigate waves reflected from meteor trails and from aurorae. Useful information is obtained both from the changes in the range of the reflected pulse, and also from the Doppler shift of the frequency. Pulses reflected at normal incidence from the ionosphere are caused to « fade » more or less rapidly by the irregularities through which they pass, and observations of this fading at comparatively closely spaced receivers gives information about the horizontal movements. Waves originating in radio stars and penetrating the irregular ionosphere fade in a similar way and observations of these « scintillations » at three receiving points give further information. The « ripples » in the ionosphere cause grosser changes in the wave received by ionospheric echo sounders and sometimes cause the reflected pulse to become multiple. These phenomena are studied with more widely spaced receivers.

The information obtained should be useful in considering the following problems of movements on a world-wide scale. The results from meteor trails and from observations of fading of a wave returned from the E layer provide information about air movements at heights between about 80 and 130 km. These movements appear to alter over the earth's surface, and have, in addition to a constant component, components which vary with the season and the time of day.

Movements in the F region are studied through observations of fading, of « ripples », and of the scintillation of radio stars. The movements of irregularities in this region are probably caused by electro-magnetic forces, and not by movements of the air. It is not yet clear whether the « ripples » represent bodily movements of the electrons, or a wave-motion travelling through electrons which are, on the average, at rest. Little is known about the world-wide variation of the movements in the F region.

Relatively few studies have been made of movements in the aurora. There appears to be some indication that the movements are predominantly along lines of magnetic latitude, but it is not clear whether this represents a movement of the electrons or of the ionising agent.

4.4. — The Atmospheric Noise Programme : Mr. F. Horner.

The atmospheric noise programme is concerned with the study of all naturally-occurring noise originating in the earth's atmosphere.

This definition includes whistlers and other related very low frequency phenomena, but these will be the subject of a separate report by Dr. Morgan.

The main feature of the atmospheric noise programme is a greatly increased effort in studying the variations of noise with frequency, with time of day, with season and with geographical position. This expanded programme has been made possible first by the fact that general agreement has been reached — and this only recently — on what characteristics of the noise should be measured, and secondly by action of the United States in furnishing apparatus for noise measurements to a number of other countries.

The main characteristic of the noise which will be measured in the general survey is the noise power averaged over a convenient time interval. Only a few stations are measuring noise power directly at present, but the number will be gradually increased and, by the end of the I.G.Y., should be in the region of twenty. It is intended that these be maintained for several years after the I.G.Y. In addition several other stations, about another twenty, are making measurements from which the noise power can be deduced indirectly.

Now although the noise power is a useful partial description of the noise, it is not sufficient, From the earliest days of radio various types of noise have been recognised, smooth noise, clicks, grinders, tweeks and so on. It is our aim to describe these noise phenomena quantitatively by measuring a series of statistical parameters. The number of stations making these more complex measurements will probably be at least ten.

Another thing we wish to know about the noise is where it comes from. A few stations will be recording the direction of arrival, but in addition, use will be made of the many networks of stations for locating thunderstorms in a regular basis. These are operated mainly by meteorological organisations, but there is clear collaboration between U.R.S.I. and WMO on this topic. Many stations will be using simple recorders designed to comb the number of lightning flashes in the vicinity of the station, and this will help to improve data on thunderstorm distributions.

Our knowledge of the mechanism of the lightning discharge, and of the way in which the radiated electromagnetic energy is propagated to great distances, needs to be improved. During the I.G.Y. renewed attempts will be made to record the field changes due

to a lightning discharge simultaneously at a number of stations and to deduce information regarding both the source and the propagation. Considering the usual distances over which the propagation phenomena are of interest, it seems appropriate that such cooperative measurements be on a regional rather than a world-wide basis, and as a start, facilities for simultaneous recording of waveforms of atmospherics are being set up at about half a dozen stations in the European area. Many stations in other parts of the world will be recording waveforms of atmospherics.

Another aspect of the noise programme of direct interest to ionospheric workers is the measurement of the sudden enhancements of noise at very low frequencies which occur in disturbed ionospheric conditions.

In noise measurements, the interference which is experienced from ionospheric sounding transmissions, superimposed on the normal traffic which occupies the major part of the frequency spectrum, greatly increases the difficulty of measurement on World Days at stations where both types of measurement are made. This problem can be solved partially by recording noise on magnetic tape in the brief intervals between ionospheric sounding transmissions, and carrying out subsequent analysis, but it may be necessary to concentrate much of the noise work on days other than World Days. Each worker will need to profit by his own experience on this aspect of the programme.

4.5. — « *Whistlers* » : Dr. M. G. Morgan.

Whistlers are a unique terrestrial phenomenon in that they have their origin at the earth's surface, are propagated into the outermost atmosphere of the earth, and are returned again to earth. Because of their magnificent global scale, they are ideally suited to synoptic study during I.G.Y. The completed theory of their generation was reported to the Xth General Assembly of U.R.S.I. in Sydney in 1952. Since that time, the validity of the theory has been clearly established and many second-order details are now under study.

Whistlers arise from the very low frequency energy which is radiated by lightning flashes. At these frequencies, the extra-

ordinary magneto-ionic wave component in the ionosphere is strongly guided along the flux of the earth's magnetic field. It is found that sufficient electron density exists at great heights so that this energy is guided along the flux of the geomagnetic field from the point of generation up into the outermost atmosphere and down to earth again at the magnetically symmetrical point in the opposite hemisphere. The propagation is dispersive, and over so long a path, a relatively large amount of time accumulates between the time of arrival of the high and low frequency components. Because the lower frequencies arrive progressively later, the original impulse is received as a descending sound called a whistler. Whereas the generating pulse may have lasted no more than a few milliseconds, the whistler may last for one or two seconds. Two principal groups of stations have been set up to study this naturally occurring phenomenon during I.G.Y. :

W 75° Group (nominal longitude)

Station		*Approximate latitude*
Thule		90° N geomagnetic
Godhavn		81
Frobisher Bay		73
Knob Lake		65
Mont Joli		60
Ottawa	Halifax	57
Hanover		55
Washington		50
Bermuda		43
Gainesville		40
Huancayo		0
Ushuaia		40° S
Port Lockroy		50
Ellsworth		60

Ottawa and Halifax are west and east of the line joining Mont Joli and Hanover and these four stations provide an areas coverage at a latitude in which whistlers are very active. All but two of the stations are now operational (Mont Joli and Ushuaia).

Pacific Group

Station	*Approximate latitude*
Kotzebue	65° N
College	65
Anchorage	60
Unalaska	60
Wakanai	35
Toyokawa	25
Brisbane	25° S
Hobart	35
Wellington	45
Dunedin	50
Macquarie Island	65

All but one of these stations is now operational (Kotzebue).

These two groups are tied together by stations at :

Stanford
Seattle
Saskatoon
Boulder
Battle Creek

In Europe and Asia, stations are operating at :

Cambridge
Kootwijk
Poitiers
Moscow
Kerguelen Island

The W75° and Pacific Groups have made arrangements to obtain radio direction finding data on sferics which produce whistlers on the east and west coast regions of North America.

VLF broadcast signals originating at Washington on 15.5 kc/s have been received in the whistler mode at Cape Horn, and it is planned to commence routine monitoring of this signal to augment the observation of naturally occurring signals.

In addition to whistlers, VLF emission from the precipitation of solar particles upon the earth are heard with the same apparatus. It is believed that these signals are generated in the manner of

travelling-wave tube operation as bunches of charge impinge obliquely upon the geomagnetic field flux in the presence of an ambient electron atmosphere. The transient signals which are generated are then propagated down the field lines in the whistler mode. These signals may be a steady, narrow frequency band of hiss, a chorus of rising musical tones also within a rather narrow frequency band, or many assume various isolated transient forms.

The study of VLF emissions is of fully as much importance as that of whistlers in understanding the nature of the earth's outermost atmosphere. Fortunately, the nature of the propagation provides that both natural phenomena may be observed with the same apparatus. Records are made on magnetic tape from a high-gain wide-band audio amplifier connected to an antenna. For synoptic studies, precise timing marks are added to the records.

4.6. — Radar Studies of Aurora : Professor A. C. B. Lovell.

The ionization produced in the 100 km region during the occurrence of aurorae is of considerable importance to the I.G.Y. programme, because the electron density is high enough to give radio echoes with relatively simple radar equipment. A world chain or radio echo equipments is operating during the I.G.Y. and these have two main tasks (i) to record the occurrence of the aurorae on a 24 hour basis thus implementing the photographic and visual programmes by providing information under conditions of cloud and daylight, (ii) to investigate the nature of the scattering of the radio waves from the various auroral formations and the relationship of the radio echoes to associated geophysical conditions. Stations cooperating in this programme have been established in Antarctica, America, Canada, Great Britain, Sweden and Norway, and important results have already been obtained.

4.7. — Radar meteor studies : Professor A. C. B. Lovell.

Very large numbers of meteors enter the earth's atmosphere every day and burn up in the 80 to 120 km region of the earth's atmosphere. During the process of evaporation ionized trails are created, and these scatter an incident radio wave so that the meteors can be recorded by the radio echo technique. The part played by this additional ionization in ionospheric phenomena is

a matter of some uncertainty and it is hoped that many of the outstanding questions can be settled during the I.G.Y. To this end the scheme of World Days has been evolved to fit in with the occurrence of meteor showers, that is the periods of intense meteor activity which take place when the earth encounters concentrations of meteor debris in space. In addition continuously operating radio echo meteor equipments have been set up in the northern and southern hemispheres to record the number of meteors entering the atmosphere at any given time. This « meteor index », which is already being published on a monthly basis, will enable ionospheric workers to correlate their results with these meteoric phenomena.

4.8. — Backscatter Soundings : Dr. A. M. Peterson.

Backscatter sounding of the ionosphere is an oblique incidence pulsed-radar method for study of the regular layers, sporadic E and a variety of irregularities which occur within the ionosphere. Whereas vertical-incidence ionospheric soundings record in considerable detail only those events occurring overhead, scatter sounding permits surveillance from a single location of a considerable region of the ionosphere, though in lesser detail. In addition, scatter soundings facilitate the study of classes of ionospheric irregularities which, by virtue of their shape and distribution in space, exhibit marked aspect sensitivity and can only be observed at oblique incidence.

A wide variety of sounders with markedly different characteristics have been used successfully for scatter soundings. Two distinct types of sounder have been developed, the « fixed-frequency » sounder and the « sweep-frequency » sounder.

Fixed-frequency sounders have normally been operated with transmissions at one or more fixed frequencies, making use of rotatable directive antennae and some suitable means of data display and recording. While a simple range-time or A-scope presentation will suffice when one is interested in measuring conditions over one particular path, for most convenient display of conditions over a large number of paths, however, a plan position indication, or « PPI » display is desirable. With a PPI display, as the directive antenna is rotated a range-azimuth polar plot is

traced out on the cathode-ray-tube screen. This display can then be photographed to provide a permanent record.

Sweep-frequency sounders are similar in many respects to the familiar vertical-incidence sweep-frequency ionosphere sounders. Certain modifications of the basic equipment are, however, required to obtain successful scatter soundings. A suitable broad-band directive antenna or group of antennae must be provided for oblique-incidence transmissions. In addition, longer pulses and narrower receiver band-widths than are used with vertical-incidence sounders often prove useful.

As is the case with most measurements to be undertaken during the I.G.Y., it is desirable to obtain simultaneously back-scatter soundings from a number of locations widely spread throughout the world. Since the number of stations must always be limited, some recommendations for the positioning and operating of the stations that will be available are being made. It appears very desirable to make simultaneous observations at different magnetic latitudes to check the latitude dependence of field-aligned ionization irregularities of both the auroral type and of the, as yet unexplained, lower-latitude variety. A distribution of stations at various latitudes will also be very valuable in the study of sporadic E. It will, for example, permit the study of the motion of patches to determine if motion in all parts of the world is uniformly westward, as is the case in the region near Stanford. A number of stations in the southern hemisphere would be valuable for this study. In the study of motion and other characteristics of sporadic E, it will also be important to provide for groups of stations giving overlapping coverage of the E region from several locations simultaneously. Since this requires station locations as close together as 1000-1500 km, it will only be possible to achieve this coverage in limited regions. One such region is planned during the I.G.Y. in western United States where there will be a chain of 13 stations. For continuous coverage of the normal F layer by the ground back-scatter technique, station spacings can be increased to 2000-3000 km.

Summarising we can say that the widespread I.G.Y. back-scatter investigations should yield important new information on :

(1) The regular layers.

(2) Sporadic E.

(3) The aurora.

(4) Meteor ionization trails.

(5) Field-aligned irregularities occurring at low latitudes.

4.9. — Comments on « Airglow » : F. E. Roach.

Approximately thirty airglow observing stations are either in operation or planned for the International Geophysical Year. In general they are oriented along approximate lines of longitude. The principal chains of stations are (1) Europe-Africa, (2) the U. S. S. R., (3) India, (4) Japan-Australia and (5) The Americas.

All observers include the measurement of the green oxygen line (5577A). Other radiations that are observed are the yellow sodium D doublet at 5890-5896A, the red oxygen lines at 6300-6364A, and the OH bands which are especially prominent in the near infra-red.

The observing methods employed in airglow studies are spectrographic and photoelectric. In order to record even the brighter airglow features spectrographically, exposures time of about 1/4 to 1 hour are required with optically fast spectrographs. The patrol spectrographs used in the auroral program have the advantage that the slit includes a vertical circle of the sky from one horizon to the other thus giving information of a synoptic nature. The photoelectric photometers used in I.G.Y. airglow studies are of two types : (1) those which observe a fixed region such as the zenith or the celestial pole and (2) those which scan the sky in a systematic fashion.

The general program is to obtain the absolute intensity of the airglow at many stations so as to develop a synoptic picture of the phenomenon. Since observations are in general possible only in the absence of moonlight and clouds only a fraction (about 1/3 to 1/5) of the night hours yield usable data at a given station. The building up of world-wide pictures thus depends on much less data than for such disciplines as ionospheric vertical soundings which can get continuous observations independent of external conditions.

The physical interpretation of the airglow will depend on the procurement of quantitative data from the many I.G.Y. stations. The current research results at the beginning of I.G.Y. suggest

that the understanding of the airglow will contribute to a basic knowledge of the structure and the dynamics of the upper atmosphere.

4.10. — The I. G. Y. World Data Centres : Dr. P. Mange.

4.11. — The I.G.Y. « World Day » Programme : Mr. A. H. Shapley.

(The above papers have not been received).

4.12. — The role of Ursigrams during the I.G.Y. : Father P. Lejay (President of the Permanent Committee on Ursigrams).

(*Translation*)

During the I.G.Y., the Ursigram Service will have two main aims :

1° This service must ensure the rapid transmission of data required for Alert decisions and for ionospheric disturbances predictions. Ursigrams will contribute partly to provide to the Boulder Centre the necessary data. By its organization, the service can in fact collect all information from magnetic, solar and other observatories and transmit the essential to the U. S. A. within the shortest delays. The gathering of regional data in the Ursigram centres and the daily exchanges between these Centres allow them to progressively establish their own predictions either for direct utilization as it will be said further, or in view of transmission for information to Boulder.

2° Geophysical and solar data are of increasing interest for particular institutions or observatories, sometimes completely isolated, which participate in the I.G.Y. observations. Without this information, such stations would be obliged to follow the I.G.Y. decisions without understanding their significance. Ursigrams will keep them informed on phenomena and there is no doubt that observers — which very often are not simple performers but qualified scientists — will find a renewed interest.

Another advantage will eventually be found by observers from a precise knowledge of phenomena evolution. These observers will in fact have the possibility of using immediately this synoptic view in the conduct of their own observations in taking the neces-

sary steps in adapting their own programme to circumstances varying with disciplines and researches involved in complement of observations required by international decisions.

The principal preoccupation of the Ursigram Committee and the principal difficulty it experienced consisted in establishing an unique organization which could satisfy prediction services, observatories and scientific users, such requirements were sometimes contradictory. In the elaboration of codes, it has been necessary to take account of the choice of possible observations, by observatories, of the delays required by prediction services, of observation and reduction schedules, and of local hours for the establishment of predictions.

A general agreement has now been obtained, after numerous meetings and correspondence. A system of codes, as flexible as to be completed if necessary, and containing alternatives to be applied in any circumstances, is now established and universally agreed.

The increase of data transmitted, of the number of observing stations and of users, was followed by a considerable development of transmissions. These were modernized and completed. An efficient support has been received from telecommunication departments in numerous countries. As a result, the I.G.Y. has been the occasion of considerable improvement in the Ursigram service, which has taken a great benefit of international efforts, while it has brought to the I.G.Y. the support of a powerful, already functioning organization. Accomplished progress leave no doubt that the Ursigram Service will become still more efficient and rapid, and will answer to the more and more numerous requirements of interested people in an increasing number of countries, to day more than half the countries adhering to U.R.S.I.

4.13. — Rockets and Satellites During the I.G.Y. : Dr. L. V. Berkner (C.S.A.G.I. Reporter for Rockets and Satellites).

Mr. President, members of U.R.S.I., and guests :

I am happy to report to you the progress and the plans that have been made on the program for the launching of rockets and satellites during the I.G.Y. Toward the end of this year the Manual on Rockets and Satellites (Volume 6 of the Annals of the I.G.Y.)

will be published to provide full information on the rocket and satellite program, but in the meantime, I welcome this opportunity to present to you the character of the program as it has been organized to date.

In the field of rocketry we can anticipate the most extensive study of the outer atmosphere by rocket methods that has been made up to the present time. Programs for the launching of rockets have been submitted by Australia, France, Great Britain, Japan, U. S., and U. S. S. R. This afternoon the various nations entering into programs of rocketry will describe these programs in considerable detail. Therefore, my remarks concerning rocket programs will be restricted to a brief summary.

During the pre-I.G.Y. period a number of nations have already launched rockets that have made observations of very considerable significance. I know, for example, that Dr. Friedman will describe during the course of this meeting the first observations obtained of X-radiation during the development of solar chromospheric eruption made as a part of the pre-I.G.Y. launching program.

The rocket program will involve the launching of rockets from the Arctic through the Temperate and Equatorial regions to the Antarctic. These observations will be directed toward many matters of interest to the members of U.R.S.I., including the study of geomagnetism, aurora, airglow, outer atmospheric science and general outer atmospheric meteorology, ionospheric physics, meteoric dust, solar ultra-violet light and X-radiation, and many related phenomena of the exosphere and the space surrounding the earth. The rockets to be launched will range from large size rockets capable of carrying many hundreds of pounds of scientific apparatus such as the Aerobee High of the U. S., the meteorological and geophysical rockets of the U. S. S. R., and the Skylark of Great Britain, through the smaller Kappa and Sigma rockets of Japan with their finely instrumented scientific heads, down to the relatively cheap and light rockoons to be launched from balloons by several nations.

The rocket program has particular significance in providing measurements of the cross section of the atmosphere that will connect our observations of the earth's surface with the more continuous observations to be made by the satellites from their

orbits within the exosphere and above the main regions of the ionosphere.

Turning now to the instrumented earth satellites, we can recall that just three years ago, the U.R.S.I. at its General Assembly at The Hague passed the following resolution :

« U.R.S.I. recognizes the extreme importance of continuous observations, from above the E-region of extraterrestrial radiations, especially during the forthcoming A.G.I.

» U.R.S.I. therefore draws attention to the fact that an extension of present isolated rocket observations by means of instrumented Earth Satellite vehicles would allow the continuous monitoring of solar ultra-violet and X-radiation intensity and its effects on the ionosphere, particularly during solar flares thereby enhancing our scientific knowledge of the outer atmosphere. »

Two nations responded to this resolution and have announced their intention to launch instrumented satellites to gather scientific information. On July 29, 1955, in Washington, President Eisenhower announced the intention of the United States to undertake this task as a part of the I.G.Y. On September 11, 1956, in Barcelona, Academician I. P. Bardin, Chairman of the I.G.Y. Committee of the Soviet Union likewise announced the intention of the Soviet Union to launch similar satellites. This effectuation of the resolution of the Union is demonstrative of the strength of international science acting through its Unions.

Since these announcements, the program of the launching of these vehicles has been proceeding vigorously. This program has involved not only the design of the satellites containing the varied experimental apparatus, but also an immense effort on the vehicles to launch the satellite, on the means for guiding the satellite into a successful orbit, on the means of recording the scientific information that the satellite gathers, and, finally, on the means for precisely tracking this satellite in its gyrations around the Earth. In the few months since the initial announcement, progress has been sufficient to permit us to look forward with considerable confidence to the probability that man-made satellites will be circling the Earth within the present year.

The satellite itself will consist of a polished spherical container that will house the elements necessary to its successful scientific performance. Among the items contained in the satellite must

be, first of all, the experimental apparatus to make the desired experiments. I shall discuss these rather fully in a moment.

Second, the satellite must contain a means of recording the results of the experiments. The experimental data accumulated during each orbit around the Earth is best stored in the form of electrical impulses describing these results. Moreover, the satellite must contain a radio receiver to advise it when to release its stored information and a radio transmitter to convey the information to the ground upon request. This means of storage, interrogation, and transmission is known as the telemetering system. To conserve electrical power on the satellite, the telemetering transmitter may act only when properly interrogated by an appropriate radio station on the ground, and, upon interrogation, transmits its information for permanent recording. Alternatively, it may, of course, transmit continuously, but in this case much of the data is lost.

Third, the satellite must contain one or more radio beacons, or, if you like, a means of shining at radio wave lengths, so that it can be seen in the radio frequency spectrum by appropriate radio receivers on the ground. Of course, the satellite can be seen visually under certain circumstances — for example, an hour or two before sunrise or after sunset — while it is still illuminated high overhead by the sun. Since at such times an observer on the ground will be in darkness, he will see the satellite as a tiny dot of light equivalent of the brightness of a 5th magnitude star as it rises in the westward and passes overhead to the east. But, such visual observations may be obscured by clouds, and, at any rate, are not frequent enough to provide the information needed about its exact track across the sky. With a suitable radio beacon, the satellite can be seen at any time of the day by suitable radio stations. With the « Minitrack » viewing device, which is a radio receiver and antenna of a very special and complicated kind, the satellite can be seen and located as it passes within a few hundred miles of the Minitrack station to a precision of better than 100 feet. I might add that this accuracy is comparable to the accuracy of visual observation using the most advanced type of Schmidt camera that will be employed in visual tracking of the satellite.

Thus, the satellite contains the experimental apparatus, the means of storage and transmittal of the experimental information,

a radio beacon to permit it to be seen precisely by radio means, and, of course, the batteries to supply electrical power to these devices for many weeks of operations. All of these devices are contained in a shiny metal sphere which in the U. S. version is a little more than 20" in diameter and which weighs a little more than 20 lbs. Quite evidently the most advanced and sophisticated electronic techniques have been necessary to compress the total of apparatus and batteries into this relatively tiny space. But, this compression is only one difficult element of the design of this satellite. It must be designed to operate in space where, in the shadow of the Earth, its temperature may drop towards absolute zero, but, when exposed to the full glare of the sun's rays, may rise towards the melting point. You can imagine the extremely difficult problems of designing apparatus so that the radiative equilibrium will maintain the apparatus within the satellite at a temperature at which its components will remain operable. It so happens that gold has most suitable radiative properties, so that many of the internal components are best plated with gold.

Before going on to the details of the scientific observations to be done by the satellites, let me mention one or two aspects of their orbits. The first satellites of both the U. S. and Soviet Union probably will travel in a generally easterly direction to take advantage of the earth's rotational energy. At the altitude nearest to the earth's surface, that is the perigee, the satellite should be a little more than 300 miles overhead. But the orbit will be rather elliptical, reaching distances rather more than 600 miles and reaching perhaps 2000 miles overhead at the apogee of its orbit. In these orbits the satellite will circle the earth once each 90 to 100 minutes — that is roughly each hour and a half — so that it will complete about 14 or 15 round trips around the earth each day. Since the scientific information must be repeated back to interrogating stations after each round trip, the earth will receive the scientific information from each satellite about 15 times a day. Since the earth rotates 15 degrees each hour under the satellite, its surface advances something more than 20 degrees or about 1000 miles as the satellite completes a round trip. Consequently, the whole surface of the earth is scanned each day, for a satellite at 300 miles can scan a band *more* than 1000 miles wide. In later satellites, as their altitude is increased, the period

of rotation around the earth will be lengthened. Of course, our only existing satellite, the Moon, which is distant 240,000 miles above the earth, circles it about once each 28 days. In fact, it is conceivable that the satellite could be launched with just the right altitude and velocity to cause it to hover almost stationery overhead. Inevitably, it would drift away slowly because of small differences between its orbital velocity and the rotational velocity of the Earth. Such a satellite would be a few earth's radii overhead. Other orbits might be a north-south orbit passing over the Poles so that a satellite would need only one interrogating station at one of the Poles, though again it would slowly precess from such an orbit. Alternatively, it might be made to follow an orbit along the sunrise-sunset path so that it would be easily visible at all times and could view the sun continuously. Of course, there are a variety of future orbits that can be selected, each of which may have some special advantage for a particular research problem.

The range of the orbit north and south of the equator cannot be less than the latitude of the launching site, though it can be more. Thus, the selection of the launching site puts some restrictions on the possible orbits. The U. S. will launch its satellites from Cape Canaveral, Florida, on an orbit that will scan the earth from 40° north to 40° south. On the other hand, the Soviet Union will launch its satellites at about 55° north on an orbit that will scan the earth approximately between the Arctic and Antarctic circles. But the satellites of either nation could eventually be made to scan the whole of the earth, though of course some additional launching energy would be required for a north-south launching to compensate for the loss of the earth's rotational energy.

After this brief discussion of the satellite itself, let me turn to the experimental programs that can be carried out with this powerful new tool during the I.G.Y. Consider first the field of meteorology.

We all know that the earth's atmosphere can be regarded as the gas of a kind of heat engine — a heat engine that receives a net gain of energy from the sun mainly from mid-latitudes to the equator. The equatorial region is the fire-box and stores this energy in water vapor that it evaporates. The atmospheric gas

suffers a net loss of energy by radiation poleward from mid-latitudes. The polar regions are the condensers of this great heat engine. The earth's atmosphere is perhaps the only great heat engine that uses a radiator as a condenser.

The transfer of heat from fire-box to condenser involves the circulation of the energy carrying gas in the connecting space — which is the circulation of the atmosphere that brings us our weather. The circulation of a gas in this way over a rotating sphere involves coupling of several successive circulation cells and tends not to be very stable. Unfortunately, the heat input and the output to the engine are not constant; the input changes as variation of equatorial cloud-cover reflects more or less of incident heat from the sun back into space; the output depends on the reabsorption of radiated heat in the atmosphere as the content of gases that re-absorb the heat radiated from the surface in the air is modified. Moreover, these variations of input and output are not known since synoptic measurements are very few over the 70 percent of the earth's surface that is inaccessible to regular observation — the oceans and the polar regions. In addition, a small change in rate of overturning of the oceans can change the heat supply to or from the atmosphere locally. All of these localized changes in input and output tend to upset the already doubtful stability of the atmospheric flow. Thus, the meteorologist of today is expected to predict the behavior of a heat engine whose input and output variations are not known; an engine that may develop hot spots of heat absorption or cool spots of excessive radiation in regions to which he has no access.

The development of these hot and cold spots may play a major part in modification of the general atmospheric circulation or in cyclogenesis. In conveying the heat from the equatorial regions towards the poles, the circulation is not as simple as it would be through a series of pipes. Instead, the heat is conveyed through coupling between a series of verticle circulation cells successively in the equatorial regions, and in the temperate zones, and in the polar regions in each hemisphere. Sometimes these cells do not transfer heat from one to another as they should with a resultant delay in the heat transfer and the buildup for unusually hot and cold spots, or a re-routing of the ordinary flow patterns. The delay may extend for a considerable time but when the break-

down occurs there may be radical effects on the weather. Such gross effects cannot be traced or understood until the whole earth is observed at very frequent intervals with appropriate measuring devices. The satellite holds promise of revolutionizing our power of observation in the field of meteorology and provides a new tool of magnificent power to the meteorologist. Among the first satellite experiments will be the attempt to measure the heat balance of the earth and the variation of the heat balance from place to place. This will implicitly involve measurement of the albedo of the earth and its long wave radiation. Thus, for the first time, the meteorologist will gain some notion of the variation of input and output energy to the atmospheric heat engine whose performance he must predict. This will be but the beginning. Not far behind is experimental mapping of the cloud and storm systems over the whole earth with delineation of changes and movements of storm systems at frequent intervals, and the observation of cyclo-genesis. The location of the hot and cold spots in the sense of excessive input to or output from the atmospheric heat engine is certainly within range of feasibility with the earth satellite. It should not be difficult to count thunderstorms or even flash frequency of lightning on the dark side of the earth, and to map development of active frontal areas. Moreover, the capability of the satellite to scan the earth quickly, and to store and transmit a large quantity of information on request, will suggest many other powerful experiments critical to meteorology. But perhaps, above all, will be the general improvement in our knowledge of the earth's exterior environment. Is it true that meteoric dust particles of microscopic size vary in density from place to place as they are swept up by the earth as it courses along its orbit; are they of the kind and numbers that can influence rainfall as Bowen suggested ? Satellite experiments can measure the size distribution of meteoric dust particles swept up by the earth in its orbit.

Let me turn now to consideration of solar radiation. We usually think of the sun as a fixed star. In fact, the visible radiation from the Sun is defined in terms of a solar constant. But radiation of short wavelengths, the ultra-violet and X-radiation from the sun, are absorbed in the high atmosphere and cannot be seen even from the highest mountain top. Fleeting rocket

observations have shown very large variations in solar radiations at such short wavelengths, variations that are more than 100 to 1 even when the sun appears quiet. With only minor visible manifestations such as small eruptions in the sun's chromosphere, the I.G.Y. rockets have found an immense increase in ultra-violet and particularly X-radiation, so that X-ray wavelengths as short as 1 Angstrom penetrate deep into the atmosphere and can be seen only 35 miles overhead. Clearly, it is important to understand the character and variation of these otherwise invisible radiation from the sun. This the satellite can do superbly. By continually recording the radiation from the sun from a vantage point outside the absorbing atmosphere, the satellite can provide us with a complete story of the character and intensity and variation of solar radiation in the ultra-violet and X-ray spectrum. Where this knowledge will lead to at the moment, no one can say. Certainly it will greatly influence our ability to predict the effectiveness of long-distance radio transmissions. Certainly it will enhance our understanding of the physics of the sun. But the occasional presence of intense X-rays in the relatively low atmosphere may have other consequences that we do not yet understand.

A third group of experiments to be done by the satellite relates to the composition of the exosphere and the particle streams that traverse it. The exosphere is the region of the atmosphere extending outside the level of the outer or F-region of the ionosphere more than 250 miles overhead. Ordinary radio observation of the exosphere is not possible because of the shielding of the intervening ionosphere. Yet there is increasing evidence from many sources that the exosphere plays an important and interesting role in our general environment. It is a region traversed by primary cosmic rays deflected by the geomagnetic field. It is the region of first impact on our atmosphere of streams of solar corpuscles ejected by the sun that produce geomagnetic disturbances and auroral displays when intercepted by the earth. It seems very likely that the sun's corona extends through the earth's orbit so the exosphere is the region of coupling between the corona and the earth's atmosphere. In fact, recently when Professor Donald Menzel was asked why geophysicists were interested in the sun during the I.G.Y., he replied : « Because we are living in it ».

By this he meant that the earth lies within the outer regions of the sun's corona.

Quite aside from these classical examples of the part played by the exosphere in governing our environment, recent studies of that strange phenomenon known as Whistlers have greatly stimulated our interest in this region that couples our earth to the space around it. Whistlers are an electromagnetic wave of a very low frequency — a few thousand cycles — that were first noticed on telephone lines in the Alps in 1886. Whistlers arise from lightning flashes whose field appears to be propagated through the exosphere far into space along a line of force of the earth's magnetic field, following the field back to the opposite hemisphere. Thus, they are heard sometimes with successive multiples spaced by a second or two of time as they are reflected back and forth between one hemisphere and the other. As many as 15 or 20 multiple reflections have been observed. Strangely enough, a late multiple is often stronger than the original reflection, as though the wave was amplified in the process. It now turns out that whistlers can be amplified in the exosphere. Particle streams from the sun and intercepted by the earth are focussed in the earth's magnetic field to form a kind of travelling wave tube amplifier. Whistler waves travelling in the exosphere acquire energy from the particle streams and seem thus to be actually amplified in the exosphere as the solar streams of particles enter the earth. Moreover, the particle streams themselves appear to generate low frequency radio noises of their own that are identified by such fascinating names as « hooks » and « hisses ».

The illustration of whistlers is only one example of the influence of the exosphere and of the surrounding space on our general environment. Many of you could cite a dozen other examples. So, it is important to understand the general relation of this region where our atmosphere is coupled to an external space filled with all sorts of debris.

The satellite provides us with means of studying this external region. By means of proton magnetometers or similar devices it will be possible to measure the force and direction of the earth's magnetic field at great heights. It should be possible to ascertain directly whether this field is distorted at great distances above the surface as it is coupled to the particles occupying or traveling

through the space of the earth's orbit. It should be possible to ascertain whether the deflection of incoming streams of particles under the influence of the geomagnetic field produces ring currents that may encircle the earth and to measure the intensity of such ring currents if they exist. It should be possible to carry out experiments in the very regions where the traveling wave amplifier — the amplifier that can enhance whistler trains — is operative.

The satellite can make direct measurement of the energy and intensity of incoming particles and particle streams including both soft and hard primary cosmic rays. I might add that the cosmic ray experiments contemplated for the satellite experiment involve continuous recording of cosmic ray counts. For this purpose a magnetic tape recorder weighing only about 6 ounces has been devised to register this information and to repeat it back to the interrogating telemetering station as the satellite passes overhead.

At this point I should mention some of what might be called the « free » experiments that can be done by the satellite. These are experiments that require no special instrumentation but only observation of the satellite orbit and its perturbations. The first of these is the measurement of atmospheric pressure at the great heights at which the satellite will travel. When the satellite was first conceived, we thought that we could calculate the atmospheric pressure at these heights with some measure of precision. But since the satellite program has been projected, the pressure has been re-calculated by many scientific groups using many different lines of evidence. Unfortunately, today it is impossible to obtain agreement among different groups as to just what atmospheric pressures and density will be encountered by the satellite to within a couple of orders of magnitude. This pressure can be derived directly by measuring the rate of acceleration of this satellite along its orbit. I hardly need add that this matter of pressure is of the utmost importance to the life of the satellite since the higher the pressure the shorter the life. The uncertainty of the pressure at the levels of the orbit makes it impossible to predict what the life will actually be until the first experiments have been done. Based on present estimates, this may vary from as little as a few days in the event the pressure is high to a life of a year or more in the event the pressure is very much lower.

A second free experiment involving only the observation of the satellite relates to geodesy. Here two distinct aspects of the orbital motion must be considered. The first is dynamical and the second geometric. The dynamical observations involve the observation of the perturbations of the satellite orbit on successive rotations to deduce something concerning gravity anomalies. In connection with other information, these observations can tell us something about the distribution of matter within the earth. By the geometrical method, that is the accurate observation of the satellite in two or three positions along the same or successive orbits, we can obtain direct information concerning the shape of the geoid, and the precise location of the points over the surface of the earth with respect to one another. I might add that the accuracy foreseeable by these methods should permit us to establish movements of the earth's crust or continental drifts within a reasonable space of time, perhaps less than a century.

A final free experiment relates to the determination of total ionization in the exosphere between the ionosphere and the level of the satellite. You will recall that the satellite will carry a radio beacon. At low altitudes of the sky, while the satellite is rising, the waves from this beacon must pass through the ionization of intervening space in such a way that the radio waves will be refracted towards the zenith. Therefore, near the horizon the satellite will appear to the radio receiver to be higher in the sky than shown by direct visual sighting. When the angle between the radio and visual position is measured at a known altitude, the total ionization between the earth and satellite can be readily computed since refraction of the radio waves by this ionization has caused the radio sighting to be elevated. If one subtracts the ionization between ourselves and the maximum of the ionosphere which is known from other measurements, we will have remaining total ionization between the ionosphere and the satellite itself. At a given station the satellite will appear at different heights on successive orbits at heights ranging successively from 300 to perhaps 2000 kilometers, so that a succession of measurements of the ionization of the exosphere at successive heights should provide us with the distribution of ionization through the exosphere.

We could go on with the description of many other possible

experiments, but I think I shall mention just one other experiment, which although it may not be done immediately, offers considerable challenge. The possibility of this experiment is specifically mentioned in the paper on the Russian satellite transmitted to me by Academician Bardin. This is the measurement of the gravitational red-shift. As you all know, in the study of many basic aspects of science, it is of vital importance to determine whether the gravitational red-shift is observed as predicted in the Einstein theory. The whole question of the properties of time as it enters dimensionally into our theories depends on the outcome of such a test. One way of undertaking this test would be to compare the relative time kept by two atomic clocks — one in the gravitational field on the surface of the earth and the second one high above the surface where the gravitational field is significantly weaker. Recently, using the atom of cesium Professor Zacharias has developed an atomic clock which is theoretically capable of keeping time to one part in 10^{11} (a billion-billion). While this accuracy has not yet been fully achieved (present clocks keep time to a part in 10^{12}, a hundred million billion), the achievement of a light-weight atomic clock of the required precision seems well within the realm of feasibility within the next few years. With such precision of time measurement by the atom, the erection of one such clock in the earth satellite would permit the direct conduct of the red-shift experiment.

In conclusion, may I remark that it is important that the most advanced technology of our time has been turned to the cause of science. I am happy to say that the participating nations have agreed to make all knowledge obtained from the flights of the satellite freely available to all. At the end of September 1957 a conference on rockets and satellites will be held at Washington at which nations of east and west alike will join hands in solving the remaining problems of the satellite flights.

The International Scientific Radio Union can view with pride the part it has played in encouraging the satellite as an instrument for peaceful scientific study for the great benefit of all mankind.

AFTERNOON SESSIONS

During the afternoon four simultaneous sessions were held. The programmes of the meetings were as follows :

1. Ionospheric Physics (*Chairman* : Sir Edward Appleton) :

(*a*) The uniform interpretation and reduction of ionograms (A. H. Shapley) ;

(*b*) True height profiles : methods, plans (J. A. Ratcliffe and E. R. Schmerling) ;

(*c*) Special observations and analyses for World Days (A. H. Shapley) ;

(*d*) I.G.Y. absorption measurements (W. J. G. Beynon) ;

(*e*) I.G.Y. drift measurements (J. A. Ratcliffe) ;

(*f*) I.G.Y. backscatter measurements (A. M. Peterson) ;

(*g*) Some results from Antarctic stations (Dr. Lepechinsky, R. W. Knecht) ;

(*h*) Discussion on the reporting and interchange of ionospheric data.

2. Geomagnetism, Aurora and Airglow (*Chairman*, F. E. Roach) :

(*a*) Synoptic analysis of geomagnetic observations (K. Maeda) ;

(*b*) The interpretation of radar auroral observations (A. C. B. Lovell, A. M. Peterson) ;

(*c*) Synoptic maps of the airglow (F. E. Roach) ;

(*d*) Discussion on the reporting and interchange of data.

3. Solar Activity and Cosmic Rays (*Chairman* : W. O. Roberts) :

(*a*) Standardization of radio noise patrols (T. Hatanaka, M. Cohen) ;

(*b*) Patrol of solar flare events by their ionospheric effects (A. P. Mitra) ;

(*c*) Solar effects on cosmic ray neutron flux (A. Weaver) ;

(*d*) Uniformity of observation and reduction (G. Righini) ;

(*e*) Discussion of data reporting and interchange (R. T. Hansen) ;

4. Rockets and Satellites (*Chairman* : L. V. Berkner) :

(*a*) Introduction (L. V. Berkner) ;

(*b*) The British Australian rocket sounding programme (L. G. H. Huxley) ;

(*c*) The U. S. I.G.Y. rocket sounding programme (J. Carl SNEDDON);

(*d*) Japan rocket programme (K. MAEDA);

(*e*) U. S. S. R. satellite and vertical rocket programme (V. A. KOTELNIKOV);

(*f*) Programme for instrumented earth satellites (J. P. HAGEN).