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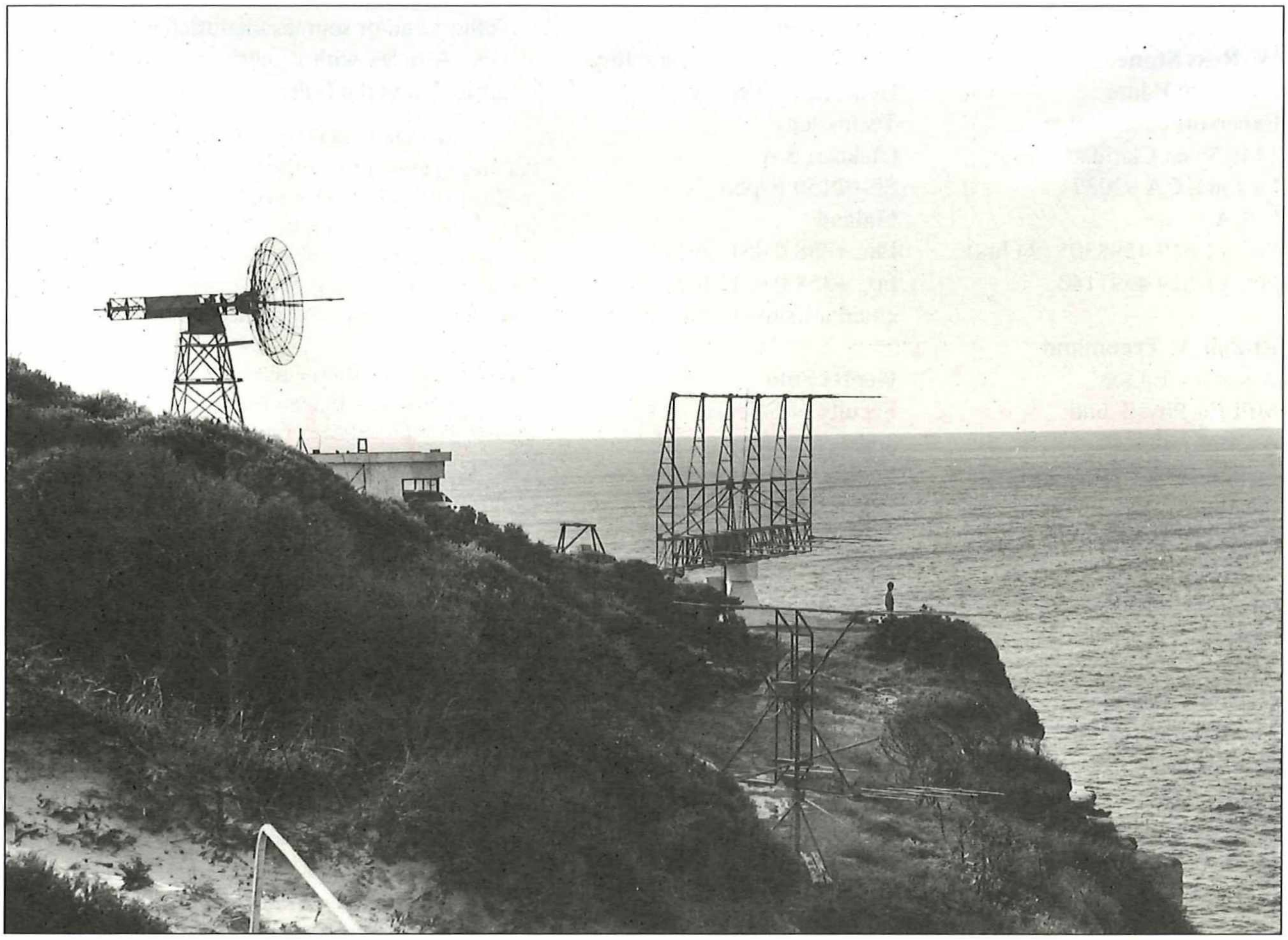

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The U.R.S.I. Radioscientist

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NOTICE TO CONTRIBUTORS

All material should be submitted direct to the Editor-in-Chief unless invited by one of the Associate Editors. Material for publication ("copy") is acceptable on paper, but is preferable in machine readable form. Please note that we cannot use Camera Ready Copy as such, though we can read it electronically by OCR machine.

Email (Internet to "dowden@physics.otago.ac.nz") is fine for pure ASCII text files, and Encapsulated PostScript Files (EPSF). Ordinary PostScript is OK but requires some work by us to convert. Text can be emailed in various forms (TEX, BinHex, uuencoded) **but must ALWAYS be accompanied by a "flat" ASCII file free of high bytes and TEX commands.** Copy is best sent on 1.44 Mbyte, 3.5 inch disk in either IBM or Mac format. Formatted text from most word processors can be read into Macintosh Word 5 (which we use), **but must always include a "flat" ASCII file as well.** We can use (and edit if necessary) equations set in MathType in Mac *Word 5* or PC *Word for Windows*.

Photographs can be monochrome or colour but must be A4 or smaller to fit our flatbed scanner and be suitable for publication in greyscale. TIFF in Macintosh form compressed onto one or several disks as self decompressing files are most welcome, but be sure to include photograph as well which we will eventually return. Computer generated line drawings (graphs, etc.) submitted only on paper do not scan well so files should be supplied on disk as EPSF or plain PostScript, or as MacDraw Pro files.

The Editor reserves the right to accept, reject, defer and/or edit any material and all material submitted. Accepted papers are not necessarily published in the immediately following issue.

COVER: The Radiophysics field station for radio astronomy at Dover Heights, Sydney, Australia, as it appeared around 1950. The site was used for coastal defence radar during WW II and for radio astronomy from 1946.

GUEST EDITORIAL

URSI at the Frontiers of Physics, Engineering and Medicine

Ever since its creation, URSI, a 74 year old Scientific Union, has regularly undertaken to review its *raison d'être*. The last occasion for such an introspective analysis was the brain-storm meeting held in 1987 at Corsendonk (Belgium). As a result, the unique place of the Union in the scientific world was reaffirmed strongly, and new fascinating prospects were opened up. The XXIV General Assembly in Kyoto, Japan (August 25 – September 1993) provided a great opportunity to appreciate the impact of recent developments and for anticipating the future trends of research in radio science.

Pierre Bauer, URSI President

Most of the scientists associated with URSI are also involved in other international scientific organisations concerned with, for example, precise electromagnetic measurements, signal processing, telecommunications, electromagnetic compatibility, study of the Earth environment, astronomy, medicine and biology. However, in URSI they find a unique forum, a place where they can meet other scientists with entirely different backgrounds, but sharing the same or similar scientific interests, all of these being related to "Electromagnetism". URSI is at the crossroads of fundamental and applied research; hence, it provides physicists, engineers and biologists with a natural common platform for fruitful exchanges of ideas and experience.

Its unique character allows URSI to play a twofold role. On one side, it offers a rich and vast scientific expertise, which finds applications in the fields of, for example, telecommunications, biology and Earth remote sensing. On the other side, it lays foundations for interdisciplinary cooperative studies and research.

Several lines of action recently taken are tangible tokens of impetus given to URSI in order to extend or reinforce its role within its sphere of competence, so as to cope with challenges issued by the evolution of science.

Commission K, the new Commission on Electromagnetics in Biology and Medicine, met for the first time in Kyoto with a scientific programme which was considered unanimously as extremely successful and promising. The expertise of URSI in telecommunications has been enhanced in the last three years thanks to a sustained effort on the part of the Scientific Committee on Telecommunications created in 1990, an initiative which was welcomed by the International Telecommunications Union (ITU). Commissions C and D, which carry a major weight in the increased emphasis put by the Union on telecommunications, held in autumn 1992 the second International Symposium on Signals, Systems and Electronics (ISSSE). The series of ISSSE will be continued, with a third Symposium to be organised in USA.

The Young Scientists Programme, which involves activities both at General Assemblies and at Scientific meetings sponsored by the Union, has been enhanced substantially. The amounts allocated to this programme from URSI's own funds and from other sources have been increased considerably, and the active participation of the new "generation" has now become a component part of URSI scientific events. In collaboration with other international agencies, the Committee on Developing Countries has been able to develop several programmes and organise workshops which serve the needs of these countries.

At last, the creation of a Network of Correspondents, consisting initially of all registrants (more than 1,200) of the Kyoto General Assembly, is intended to pave the way for improved communication and exchanges between scientists of the URSI community. It should also encourage a closer association of individuals with URSI, and promote the development of interdisciplinary research.

One of the aims of the URSI Press is to reflect both the vitality of the Union, and the quality and soundness of research in every field pursued by it. It is indeed most gratifying to read the various publications sponsored by URSI : the Radioscientist and the URSI Information Bulletin (which will be merged in the future), the Review of Radio Science and Modern Radio Science. The conclusion to be drawn from such an exercise is that our Union is attracting the best scientists in the field and serves a well defined objective at the forefront of science.

The URSI community is entitled to take pride in its mission: to promote and organise international research in radio science.

Pierre Bauer

Pierre Bauer was elected President of URSI at the XXIV General Assembly at Kyoto, Japan. He previously served as Chairman of Commission G (1981-84) and as Vice President and Treasure of URSI (1990-93).

FROM THE EDITOR

This is the last issue of the original *Radioscientist*. The next issue of the URSI magazine will appear in March (on time, unlike this one) as the *Radioscientist* **Bulletin** (I prefer the name like this without hyphenation so that "Radioscientist" is an adjective qualifying "Bulletin"). Included in this issue is a liftout insertion about membership as an URSI Correspondent. Read it carefully and follow instructions or you may never see the new *Radioscientist* **Bulletin**!

The electronic URSI NEWS has begun. The first issue is reproduced later in these pages where you will find how to get onto the emailing list.

Many issues of the *Radioscientist* have lacked **Letters** but here you will find an aggressive return. These are the sort of **Letters** you find in *Physics Today*, for example, and I consider them appropriate for the *Radioscientist* and, so in turn, for the *Radioscientist* **Bulletin**. If you have views on the appropriateness or on the issues discussed, write a **Letter.**

The article on *Basic Radiation Fields* by James Wait is from his book, now out of print, for which he holds the copyright. An interesting feature is that he derives the fields produced by an elementary dipole "without the use of complicated dyadic Green's functions," as he points out, but also even without using retarded vector potentials.

The cover article is from the *Proceedings of the Astronomical Society of Australia* (**4**, pp. 349-357, 1982), reprinted with permission in memory of John Bolton. The article relates several discoveries made on these instruments — including the hole-in-the-ground dish built by the scientists themselves. During WW II, I lived at Dover Heights (as a pre-teen) and wondered about the "listening post" as the defence radar was known to the locals.

LETTERS

ELF EM fields and health

The Commission K tutorial as delivered at the General Assembly in Kyoto was very misleading, particularly to attendees not from Commission K. Let me pick two examples and add two comments.

The first example has to do with the relation between extra-low-frequency electromagnetic fields (ELF-EMF) and health effects. Citing a study done by researchers at the Karolinska Institute, the speaker said "... and this will prove beyond a reasonable doubt the relation between power lines and a health effect" (like leukemia). The exact health effect from the Karolinska study doesn't matter, because there is a second Swedish study done independently and covering a large group of subjects over several years, as in the Karolinska study. Every association with a particular health effect in one study was not found in the other (*Science*, letter Volume 260, p.13, 2 April 1993)! The speaker made no reference to the conflicting results of the two studies leaving the audience with incomplete information and the wrong impression.

The second example has to do with breast cancer. The speaker said "there is probably a relation between ELF-EMF and breast cancer." Any listener unfamiliar with the literature would assume breast cancer in women. In fact, the report in the literature refers to a few cases of breast cancer in *men* in a very large number of men studied and without a reasonable control group for comparison. Again, a misleading impression.

Neither of these examples is in the tutorial presented in *Modern Radio Science 1993*, although they were in the oral version at Kyoto.

Finally, in the lecture there was an uncalled for personal attack on a respected physicist who had reminded the community that all systems not at absolute zero have electrical noise and, in the case of cells in the human body the noise is significant, up to several orders of magnitude stronger than the fields induced in cells by power lines and video display terminals. In engineering terms, the signal-to-noise ratio in a cell is orders of magnitude less than one, the signal is swamped by the noise, a very serious problem in an already complicated field. Interested participants should read Chapter 37 in the *Review of Radio Science* for a more balanced account of the state of the field.

W. E. Gordon
Honorary President, URSI

W. R. Adey replies —

Since Professor Gordon apparently has no background in bioelectromagnetics or related biomedical sciences, it is difficult to know whether to take his remarks seriously. I respond simply because his remarks are totally at variance with a broad and growing body of factual information.

Suffice it to point out that the Federation of American Societies of Experimental Biology (FASEB), with member societies covering the entire spectrum of medical sciences and a combined membership exceeding 20,000, has held invited symposia on bioelectromagnetics at its Annual Meeting for the past three years. My subject material dealt accurately and precisely with the major topics of these symposia.

Please allow me to deal *seriatim* with the points raised by Professor Gordon.

Professor Gordon alleges that I stated that the Karolinska power line study "will prove beyond a reasonable doubt the relation between power lines and a health effect". I made no such statement, nor is it in the text of my paper. The truth is far different. I showed a slide with a (correct) quote from a leading Swedish scientist in bioelectromagnetic research, Dr Kjell Hansson Mild, of the Swedish National Institute of Occupational Health, who said that the Karolinska study "is remarkably clear in pointing to a connection between cancer and magnetic field exposure. This study confirms earlier findings with astonishing precision."

Based on this Karolinska study, the Swedish Government established a National Electrical Safety Agency on the day following release of the Karolinska study; so that whatever may have been the findings in the unspecified "second Swedish study" cited by Professor Gordon, one may assume that its findings were not considered of equivalent value by the Swedish authorities.

Moreover, as Professor Mild has pointed out, the Karolinska study "confirms earlier findings with astonishing precision." The Karolinska study is the first study to add a factor of measured dose-dependence. It is one of four studies in peer reviewed literature that have found a relationship between childhood leukemia and proximity to power lines [Savitz et al. (1988) in Denver; London et al. (1991) in Southern California; and Olsen et al. (1993) in Denmark], with measured magnetic fields or use of wiring codes as a surrogate measure for long-term magnetic field exposure. Moreover, Davis and Milham (1989) found 5 deaths in 7 years from B cell lymphoma in a work force of 350 aluminium plant workers exposed to fields from 120,000 Amp smelting pots; and clear evidence of immunosuppression (reversed T4 helper-TB suppressor lymphocyte ratios) in 14 of 23 non-lymphomatous workers.

Professor Gordon's allusions to my discussions of breast cancer are even less accurate. He states that "the report in the literature refers to a few cases of breast cancer in *men* in a very large number of men studies and without a reasonable control group for comparison." In fact, I showed two slides taken from the studies of Matanoski et al. (1990) from the John Hopkins School of Public Health.

These investigators examined subsets of 4547 cable splicers and 9561 central office technicians from a population of 50,582 New York telephone workers (the control group that Professor Gordon says did not exist). These workers in telephone switch rooms are exposed to a mix of soldering fumes and solvents, as well as to 60 Hz fields not exceeding 0.4 μT, and to switching fields. This study reported a standardised incidence ratio (SIR) of 6.5 for male breast cancer, and is one of three reports of an excess male occupational risk (Demers et al. 1990; Tynes and Andersen, 1990).

Nor has the study of breast cancer risk been restricted to men, as Professor Gordon asserts. In postmenopausal women using electric blankets throughout the night, the odds-ratio for breast cancer has been reported at 1.31 (Vena et al. 1991). Matanoski links this risk to interference by the fields with normal pineal melatonin cycling, an essential requirement for normal oestrogen receptor formation in the breast and now tentatively linked to risk of breast cancer.

Professor Gordon's final remark about "an uncalled for personal attach on a respected physicist" is apparently a reference to slides which I showed, totally without comment, of remarks by Professor Robert Adair that are typical of his many scurrilous attacks on those who have pioneered the fields of nonlinear electrodynamics and nonequilibrium processes. With far more justification, I might express outrage on behalf of the physics community for Professor Adair's evaluation of work pioneered by the late Professor Herbert Frohlich, whose monumental contributions in the fields of superconductivity and on the role of coherent charge states in biomolecular systems have laid many of the foundations for the new and burgeoning field of bioelectromagnetics.

But then I am not a physicist, and do not presume to tread with such blundering nonchalance into realms beyond my professional expertise, as Professor Gordon and his ilk apparently feel so free to do.

As a final parenthesis, one may wonder why Professor Gordon made no attempt to intercede in the discussions that followed my lecture at the Kyoto URSI General Assembly. His points of view would have added a refreshing perspective, and there was very ample opportunity.

W. Ross Adey, M.D.
Associate Chief of Staff for Research and Development
Loma Linda University School of Medicine

W. E. Gordon replies —

With regard to the above reply, my background in bioelectromagnetics is a year's immersion in assessing the state of power line and video display terminal frequencies and health with a panel composed of medical doctors, physiologists, cell biologists, epidemiologists, engineers, physicists, and statisticians. The panel collectively evaluated the published literature (1000+ articles) and produced a book, *Health Effects of Low Frequency Electric and Magnetic Fields*, a summary of the book in pamphlet form and in *Environmental Science and Technology*, January 1993 and a letter to *Science*, vol. 260, 2 April 93.

The Karolinska paper and the second Swedish study are compared in the *Science* letter. On the breast cancer issue my remarks stand. The uncalled-for personal attack continues in Dr. Adey's letter. The Tutorial Session did not include time for comments since the speaker fully utilized the time available, and the Chair promptly adjourned the session.

electronic URSI NEWS

The next three pages show how the first (actually "1.1") issue of the new "electronic URSI NEWS" should have appeared on the screens of the recipients. The file was set in a monospaced font (Courier 10) to make this so.

If you have a unique email address (NOT one care of "Postmaster") send a short email (e.g., "Please add...") to ursi@physics.otago.ac.nz. Please do not use fax or ordinary mail to do this since I cannot then be sure that the address you provide is correct. I will use the address which Internet provides to "Reply", not the address you give me, unless you explain otherwise. Further details are given in electronic URSI NEWS below.

The addresses below did not work. If you can identify yourself here, just send "ursi" an email to have it fixed. Some addresses were erased (shown below as "<>") because they could not be sent. All the others were sent but were returned as "unknown host" or "unknown user".

Bozsoki, I. .... <t-bozsoki@nov.mht.bme.hu>
Buzek, O. .... <ure68@cspgcs11.bitnet>
Chugunov, ... <chugun@appl.hhov.su>
Cohen, R.J. .... <rcb@star.jb.man.ac.uk>
Fiala, V. .... <frbl@cspgig11.bitnet>
Gallagher, T.G. .... <tomgalla@irlearn.0>
Hagelin, Sven .... <svehag@foa.lin.se>
Hahn, S. .... <zrhs@plwatuzi.bitnet>
Holt, John .... <jmh@chaos.haystack.edu>
Jacobson, Abram .... <ajacbson@lanl.gov>
Karasek, M. .... <>
Katila, T. .... <lkt-tk@finhut.hut.fi>
Kriezis, E.R. .... <mkrtezis@vergina.eng.auth.gr>
Maeda, Hiroshi .... <hiroshi@fourier.kyushu-u.ac.jp>
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Matus, F .... <matus@espgas11.bitnet>
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At the Kyoto General Assembly Banquet, August 30, 1993, in the Takaragaike Prince Hotel. Left to right: Hiroshi Matsumoto, Mrs. Matsumoto, Sogo Okamura, Mrs. Okamura, M. Morimoto, Mrs. Okoshi, Takanori Okoshi.

electronic

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Welcome to the issue "# 1.1" of the electronic URSI NEWS, a paperless version of the original URSI NEWS of 1987-1990. This issue is for (i) those whose addresses I received from kind readers of # 1.0 who corrected my garbled versions (many thanks - sorry I did not acknowledge individually), and (ii) those who couldn't read # 1.0 because I forgot to save it as "Text Only with line break" before sending by "URSI mailer" so some received each paragraph as one long line. This issue and future issues is/will be 68 characters long. I hope this fits all screens. If not, please let me know. I also forgot the "signature" designed for Eudora. If you want to print this out as it appears on my screen, use Courier 12 or any other monospaced font.

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The purposes of the electronic URSI NEWS are:

1. To get information to you (as an URSI person) which cannot wait for the next issue of the Radioscientist Bulletin (e.g. last minute changes to URSI conferences and sessions).

2. To provide two-way electronic communication through URSI NEWS for the URSI community, particularly for those in countries where conventional communication by paper is slow or unreliable or expensive. This electronic communication would be mainly in the form of "Letters to the Editor" but could also include person-to-person email using the address list we will publish in URSI NEWS (probably in the next issue - after I have received requested additions, subtractions, and modifications to these email addresses).

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The present email address list consists of (i) those who added their names to forms circulated at Commission business meetings or pinned on the notice board at Kyoto and (ii) those "officials" listed in the 1992 Bulletin who provided email addresses in Internet form. On sorting into countries I found several having the same userid so I added only one of each on my list. I had to omit any to "postmaster" since my mailer cannot send names as well. A few addresses are inadequate in the Bulletin or on the handwritten list (or were misread by us).

Of the 142 addresses to which "URSI NEWS 0" (a dummy for address testing) was sent, 41 were returned as "unknown". Readers of "URSI NEWS 1" sent me corrected versions of several of these. Remaining ones are:

(this list appears in full on the previous page of this issue of *the Radioscientist*)

I will print this list (with names as well) in the "December" issue of the Radioscientist, so they can email me their correct Internet address (see below).

If you wish to be added to (or be removed from) the list, or if we have your name or address wrong, please email me at ursi@physics.otago.ac.nz. I expect your name, brief address and email address will appear in Internet form on the header I get from your email. If you want to be really helpful, include this information in Internet form like so:

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Dowden  R.L.    New_Zealand     <dowden@otago.ac.nz>
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Note that there are FOUR fields separated by a tab or one or more spaces – your family name, given name or initials, country, and finally your full <Internet address>. Note also use of "." or "_" to avoid making extra fields. This form is what I use to sort by country and by family name. Even if you receive email on a network other than Internet (e.g., bitnet, DECnet (SPAN), GSFCmail, JANET, NASA.MAIL, OMNET, UUCP), put <address> in Internet form or at least tell me which network you use. Despite wanting all this, I can only use the address within <> for sending URSI NEWS.

I had intended that certain issues of URSI NEWS may be limited to specific Commissions. The idea was to save you getting issues you don't want, but this just is not possible for me to implement since there are so many different combinations. So sorry, you will get all issues or none!

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Feel free to FORWARD this or any "issue" of URSI NEWS to colleagues who want it, and/or to print it out for placing on a notice board. This is particularly important if you are the only one of the many using the same user account. This will also help to get the message to the 41 whose addresses don't work at present. FORWARDing to a list of local recipients – a sort of electronic chain letter! – could be a way of reducing costs if you have to pay for incoming international email.

So far, this URSI NEWS costs me (and URSI) nothing. When the huge volume of outgoing email is discovered by the powers that be here, this may change. So such a chain letter system may be necessary. I use "URSI Mailer", a program in C made for me which works on UNIX machines, to send URSI NEWS to an address list on a file. The mailers "Eudora" and "elms" can't handle large address lists (> 100 entries). If you wish to use this to forward future issues of URSI NEWS, let me know.

Getting "junk email" is worse than the paper sort. It can fill up your disk allocation and bounce back wanted email, so we must ensure that URSI NEWS isn't junk email to some people. If YOU don't want URSI NEWS – tell me! You may get two copies because I used two valid addresses to you. If so, tell which one I should use.

===

Sorry, there's only an old "news" item (see below) in this issue of

URSI NEWS because I took so long to get the mailer going. There will be news, and future issues of URSI NEWS, only when I get items like this by email. You are both the readers and writers. Nothing in, nothing out! Contributions or "Letters" can be (and should be) quite short – even only a line or two. All may be edited (but only very rarely) and must include the author's name. Any email sent to this address ("ursi") will be considered a submitted contribution unless clearly stated otherwise. Checking of submitted news reports is not possible so we are relying on rapid email response from YOU if you read something here which is incorrect or incomplete. The Editor takes no responsibility. Other Editorial policy will be worked out progressively – any suggestions on this are very welcome.

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NASA's ambitious dual SETI programme, the High Resolution uwave Survey, formerly uwave Observing Project, has apparently "had its plug pulled" by the U.S. Congress, which is a major disappointment. There has been surprisingly little news about it—I didn't even get the usual urgent appeal for funds from the Planetary Society, of which I am a member—all I saw was a tiny news item in the Denver paper. Seth Shostak of the SETI Institute did indicate they were trying to get private funding to carry on; I have heard no more. If anyone is interested, Internet addresses of those concerned are:

Paul Horowitz, Harvard: paulh@huhepl.HARVARD.EDU
SETI: lemar@seti.edu.ar
Seth_Shostak@setigate.seti-inst.edu

Horowitz is co-author with Carl Sagan of the interesting paper on the META project in Sep. 20 'Astrophysical Journal'. Lemar, in Buenos Aires, is editor with Seth Shostak of the newsletter of the SETI Institute in Mt. View, California.

Incidentally, somebody at Carl Sagan's lecture here on asteroid impacts and mass extinctions (us...?) said during question time that there should be a search for intelligent life in the US Congress. Very apt.

Roger Williams, Dept. of Commerce Boulder Labs


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Basic Radiation Fields

James R Wait
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Abstract. We present a tutorial exposition* of the physical derivation of the electromagnetic fields of small current and loop elements in a homogeneous conducting medium. We avoid the use of complicated dyadic Green's functions which abound in most classic text books on electromagnetic theory. We depend heavily on the use of electric and magnetic Hertz vectors. Great simplification is achieved by beginning with the quasistatic forms for the dipole fields of these elementary sources. It is hoped students will find our approach a helpful adjunct to the more conventional fare in undergraduate and first year graduate courses in electrical engineering.

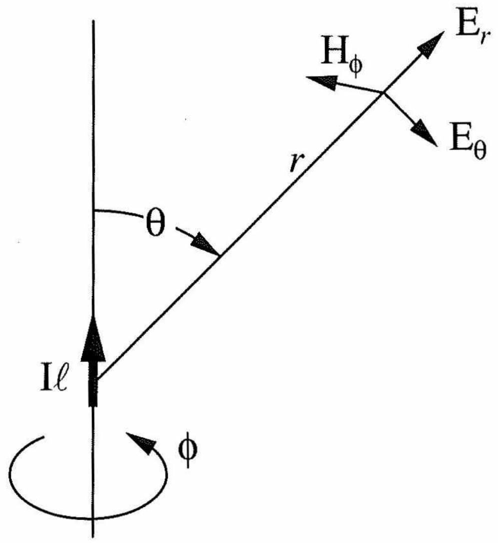


Fig. 1. Electric dipole, or current element of infinitesimal length, and spherical coordinate system.

1. RADIATION FROM A CURRENT ELEMENT

A basic building block in the analysis of radiating systems is the current element or electric dipole. We will present a direct derivation of the electromagnetic fields of such a dipole that begins with the static field behaviour.

With respect to conventional spherical coordinates (r, θ, ϕ), the dipole is located at the origin and is oriented in the polar or z direction, as illustrated in Figure 1. The surrounding medium is assumed to be homogeneous with electrical constants σ, ε, and μ. The "dipole" is to be regarded as a current element or filament of length ℓ carrying a constant current I throughout its length. The current density J at some point P at distance r from the dipole, large compared with its length, is then deduced to be the resultant of a current point source at $z = \ell/2$ and a current point sink at $z = -\ell/2$. Then it easily follows that

$$J_r = \frac{I\ell\cos\theta}{2\pi r^3} \qquad (1a)$$

$$J_\theta = \frac{I\ell\sin\theta}{4\pi r^3} \qquad (1b)$$

and

$$J_\phi = 0$$

where we have assumed $r >> \ell$. The development of equation (1) is fully analogous to Equations 1–32 and –33 [1] See also Chapter 1, Section 1.15 [1].

*This material closely follows first part of Chapter 6 of Reference [1] but corrections have been made.

Using Ampere's law, we now deduce that the corresponding magnetic field H_ϕ is related to J_r via

$$\int_o^{2\pi} H_\phi r\sin\theta\, d\phi = \int_{\phi=o}^{2\pi}\int_o^{\theta} J_r r^2 \sin\theta\, d\theta\, d\phi \qquad (2)$$

This is a statement that the total current through a ring of radius $r\sin\theta$ is equal to the magnetic field integrated around the ring. It easily follows that

$$H_\phi = \frac{I\ell\sin\theta}{4\pi r^2} \qquad (3)$$

By symmetry it is evident that

$$H_r = H_\theta = 0$$

An application of Ohm's law to (1a) and (1b) tells us that

$$E_r = \frac{I\ell\cos\theta}{2\pi\sigma r^3} \qquad (4a)$$

$$E_\theta = \frac{I\ell\sin\theta}{4\pi\sigma r^3} \qquad (4b)$$

In fact (3), (4a) and (4b) are the nonzero field components E_r, E_θ, and H_ϕ of a purely static dipole in the medium of conductivity σ. We can now generalize the results to a time-varying field, with, say, a harmonic time factor exp ($i\omega t$), in the following fashion: first of all, we write Ohm's law in its general form,

$$\mathbf{J} = (\sigma + i\varepsilon\omega)\mathbf{E} \tag{5}$$

so that the electric field near the dipole must behave as

$$E_r = \frac{I\ell \cos\theta}{2\pi(\sigma + i\varepsilon\omega)r^3} \tag{6}$$

$$E_\theta = \frac{I\ell \sin\theta}{4\pi(\sigma + i\varepsilon\omega)r^3} \tag{7}$$

Now Maxwell's equations for the present configuration are given by

$$\frac{\partial}{\partial r}(rE_\theta) - \frac{\partial E_r}{\partial \theta} = -i\mu\omega r H_\phi \tag{8}$$

$$\frac{\partial}{\partial \theta}(\sin\theta\, H_\phi) = (\sigma + i\varepsilon\omega) r \sin\theta\, E_r \tag{9}$$

$$\frac{\partial}{\partial r}(rH_\phi) = -(\sigma + i\varepsilon\omega) r E_\theta \tag{10}$$

By inserting the latter two equations (for E_r and E_θ) into the first, we deduce that

$$\frac{\partial^2 (rH_\phi)}{\partial r^2} + \frac{1}{r}\frac{\partial}{\partial \theta}\left[\frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\, H_\phi\right)\right] - \gamma^2 r H_\phi = 0 \tag{11}$$

where $\gamma^2 = i\mu\omega(\sigma + i\varepsilon\omega)$. An appropriate solution of (11) is evidently

$$H_\phi = \frac{I\ell}{4\pi r^2}(1 + \gamma r)e^{-\gamma r}\sin\theta \tag{12}$$

This has the appropriate outgoing behaviour as $r \to \infty$ and it reduces to (3) as $\gamma r \to 0$. Also, as $\omega \to 0$, it tends to the static form (3) for any r. Finally, by using (9) and (10), we deduce that the electric field components corresponding to (12) are

$$E_r = \frac{I\ell \cos\theta}{2\pi(\sigma + i\varepsilon\omega)r^3}(1 + \gamma r)e^{-\gamma r} \tag{13}$$

$$E_\theta = \frac{I\ell \sin\theta}{4\pi(\sigma + i\varepsilon\omega)r^3}(1 + \gamma r + \gamma^2 r^2)e^{-\gamma r} \tag{14}$$

These, of course, reduce to the quasi-static forms (6) and (7) as $|\gamma r| \to 0$, and they also reduce to the purely static forms (4a) and (4b) as $\omega \to 0$.

Exercise: Show that if we define an auxiliary function A by

$$H_\phi = \frac{\partial A}{\partial r}\sin\theta \tag{15}$$

A satisfies

$$\frac{\partial}{\partial r}\left(r^2 \frac{\partial A}{\partial r}\right) = \gamma^2 r^2 A \tag{16}$$

and

$$A = \frac{I\ell e^{-\gamma r}}{4\pi r} \tag{17}$$

Exercise: Verify directly that (12), (13) and (14) satisfy Maxwell's equations.

Exercise: Show that when $|\gamma r| \to \infty$,

$$E_\theta \cong \eta H_\phi \tag{18}$$

where

$$\eta = \left(\frac{i\mu\omega}{\sigma + i\varepsilon\omega}\right)^{1/2}$$

and

$$H_\phi \cong \frac{\gamma I\ell e^{-\gamma r}\sin\theta}{4\pi r} \tag{19}$$

For lossless media ($\sigma = 0$) we see that $\gamma = i\beta$, where $\beta = (\varepsilon\mu)^{1/2}\omega$. Then we find that

$$H_\phi \cong \frac{\gamma I\ell e^{-\gamma r}\sin\theta}{4\pi r} \tag{20}$$

$$E_r = \frac{I\ell}{2\pi i\varepsilon\omega r^3}(1 + i\beta r)e^{-i\beta r}\cos\theta \tag{21}$$

$$E_\theta = \frac{I\ell}{4\pi i\varepsilon\omega r^3}(1 + i\beta r - \beta^2 r^2)e^{-i\beta r}\sin\theta \tag{22}$$

If we now think of the current element as two time-varying charges $+q$ and $-q$ separated by a small distance ℓ, we can replace I by dq/dt, or $i\omega q$, and then (13) and (14) are replaced by

$$E_r = \frac{q\ell}{2\pi\varepsilon r^3}(1+i\beta r)e^{-i\beta r}\cos\theta \qquad (23)$$

$$E_\theta = \frac{q\ell}{4\pi\varepsilon r^3}(1+i\beta r-\beta^2 r^2)e^{-i\beta r}\sin\theta \qquad (24)$$

From these we recover the appropriate electrostatic formulas

$$E_r = \frac{q\ell\cos\theta}{2\pi\varepsilon r^3} \qquad (25)$$

$$E_\theta = \frac{q\ell\sin\theta}{4\pi\varepsilon r^3} \qquad (26)$$

in the limit as $\beta r \to 0$.

2. THE HERTZ VECTORS*

In dealing with the electromagnetic fields produced by current-carrying wires [1], it is convenient to employ the Hertz vector $\tilde{\Pi}$. For a homogeneous medium we define it such that its curl leads back to the magnetic field vector **H**. The constant of proportionality is chosen to agree with accepted convention [2]. Thus we write

$$\mathbf{H} = (\sigma + i\varepsilon\omega)\,\mathrm{curl}\,\tilde{\Pi} \qquad (27)$$

Then from Maxwell's equations

$$\mathbf{E} = \mathrm{curl}\,\mathrm{curl}\,\tilde{\Pi} \qquad (28)$$

or

$$\mathbf{E} = -\gamma^2\tilde{\Pi} + \mathrm{grad}\,\mathrm{div}\,\tilde{\Pi} \qquad (29)$$

To avoid conceptual difficulties, we elect to leave $\tilde{\Pi}$ undefined right at the impressed source(s) of the electromagnetic field. However, the form of the Hertz vector near a source can be determined from prior considerations. An example is given in what follows.

In the case of a current element $I\ell$ located at the origin of a cylindrical coordinate system (ρ, ϕ, z) and oriented in the z direction, we are led to write

$$\tilde{\Pi} = (0, 0, \Pi_z) \qquad (30)$$

where

The first systematic use of these vectors was made by the Dr Heinrich Hertz, Professor of Physics in the University of Bonn, (Wiedmann's Ann. Vol.36, 1-22, 1989).

$$\Pi_z = \frac{I\ell}{4\pi(\sigma+i\varepsilon\omega)r}e^{-\gamma r} \qquad (31)$$

It can be readily verified that this choice leads to the required form for the fields produced by the current element. For example, we may note that

$$H_\phi = (\sigma+i\varepsilon\omega)\,\mathrm{curl}_\phi\,\tilde{\Pi} = (\sigma+i\varepsilon\omega)\frac{\partial\Pi_z}{\partial\rho}$$

$$= \frac{I\ell}{4\pi r^2}(1+\gamma r)e^{-\gamma r}\sin\theta \qquad (32)$$

and

$$r = (\rho^2+z^2)^{1/2} \quad \text{and} \quad \sin\theta = \frac{\rho}{r}$$

Exercise: Employ (28) to obtain explicit expressions for E_ρ and E_z for the current element and show that these are consistent with (13) and (14).

We argue that any distribution of applied or impressed currents can be represented as a superposition of individual current elements. For example, for an infinitesimal volume bounded by the lines of current flow and two (cross-sectional) surfaces da normal to them, the current in the volume element is $J\,da$, where J is the impressed current density. In the case where the vector current density has only a z component $\delta\Pi_z$, is given by

$$\delta\Pi_z = \frac{J_z da\,\ell}{4\pi(\sigma+i\varepsilon\omega)}\frac{e^{-\gamma R}}{R} \qquad (33)$$

where ℓ is the length of the current element and R is the distance from the current element to the observation point.

Obviously, now we may replace $da\ \ell$ by the elemental volume dv and integrate over the volume V containing all the source elements to yield an expression for the resultant Hertz vector that has only a z component:

$$\Pi_z = \frac{1}{4\pi(\sigma+i\varepsilon\omega)}\int_V \frac{e^{\gamma R}}{R}J_z dv \qquad (34)$$

Similar equations would relate the x and y components of the Hertz vector to the x and y components of the impressed currents. Thus in vector form we write

$$\tilde{\Pi} = \frac{1}{4\pi(\sigma+i\varepsilon\omega)}\int_V \frac{e^{\gamma R}}{R}\mathbf{J}\,dv \qquad (35)$$

where **J** here denotes the impressed current density vector. The corresponding field vectors are then obtained by operating on (35) with the use of (27) and (29). The resulting expressions are valid only for a homogeneous region of infinite extent.

We now return to the basic form of Maxwell's equations that include a source of electric current density **J**. These are

$$\text{curl}\,\mathbf{E} = -i\mu\omega\mathbf{H} \quad (36)$$

$$\text{curl}\,\mathbf{H} = (\sigma + i\varepsilon\omega)\mathbf{E} + \mathbf{J} \quad (37)$$

for the usual time factor exp $(i\omega t)$. Then on using (29) and (37), we see that

$$\text{curl curl}\,\tilde{\Pi} - \text{grad div}\,\tilde{\Pi} + \gamma^2\tilde{\Pi} = \frac{\mathbf{J}}{\sigma + i\varepsilon\omega} \quad (38)$$

which is applicable for a homogeneous region. This equation can be written in symbolic form

$$(\tilde{\nabla}^2 - \gamma^2)\,\tilde{\Pi} = -\frac{\mathbf{J}}{\sigma + i\varepsilon\omega} \quad (39)$$

where

$$\tilde{\nabla}^2 = -\text{curl curl} + \text{grad div}$$

is a vector operator. Actually, in rectangular coordinates we may express it as follows:

$$\tilde{\nabla}^2\,\tilde{\Pi} = i_x\,\nabla^2\Pi_x + i_y\,\nabla^2\Pi_y + i_z\,\nabla^2\Pi_z \quad (40)$$

Using the development of the preceding section, we can now assert that for an unbounded region (35) is a solution of the imhomogeneous Helmholtz equation given by (39.

The Hertz vector $\tilde{\Pi}$ that we have introduced is associated with the impressed *electric* current density **J** in the homogeneous region under consideration. Sometimes, it is convenient to employ the magnetic Hertz vector $\tilde{\Pi}^\circ$. It is defined in an analogous fashion by saying that for a homogeneous region the electric field may be derived from

$$\mathbf{E} = -i\mu\omega\,\text{curl}\,\tilde{\Pi}^\circ \quad (41)$$

Then from Maxwell's equations

$$\mathbf{H} = (-\gamma^2 + \text{grad div})\,\tilde{\Pi}^\circ \quad (42)$$

A good example of a situation where the magnetic Hertz vector is useful is when we wish to compute the field of a small loop of wire carrying a uniform current I. The loop of area dA is located at the origin of a cylindrical coordinate system $(\rho,\ \phi,\ z)$ and oriented in the axial direction. We discussed the static solution for this problem in [1, Chap.1] where we showed that magnetic fields could be derived from the gradient of a scalar potential. We also introduced the concept of the Hertz vector in that context. The result can be generalized to the dynamic cases by analogy with the above treatment for the electric current element. Thus we are led to write

$$\tilde{\Pi}^\circ = (0,\ 0,\ \Pi_z^\circ) \quad (43)$$

where

$$\Pi_z^\circ = \frac{IdA}{4\pi R}e^{-\gamma R} \quad (44)$$

where R is the distance from the small loop to the observer. Clearly,

$$(\nabla^2 - \gamma^2)\,\tilde{\Pi}^\circ = 0 \quad (\text{for } R \neq 0) \quad (45)$$

where ∇^2 is the laplacian operator in rectangular or cylindrical coordinates.

Using (41) and (42), we now see that the nonzero field components of the small loop in spherical coordinates $(r,\ \theta,\ \phi)$ are

$$E_\phi = \frac{i\mu\omega IdA}{4\pi r^2}(1 + \gamma r)e^{-\gamma r}\sin\theta \quad (46)$$

$$H_r = \frac{IdA}{2\pi r^3}(1 + \gamma r)e^{-\gamma r}\cos\theta \quad (47)$$

$$H_\theta = \frac{IdA}{4\pi r^3}(1 + \gamma r + \gamma^2 r^2)e^{-\gamma r}\sin\theta \quad (48)$$

As $|\gamma r| \to 0$, these expressions reduce to the appropriate static forms. Also, as $|\gamma r| \to \infty$, we see that

$$E_\phi \cong -\eta H_\theta \cong \frac{-i\mu\omega\,IdA\,e^{-\gamma r}\sin\theta}{4\pi r} \quad (49)$$

To emphasize the duality of the small, linear, electric current element and the small loop carrying a circumferential current, we exploit the magnetic current concept. Thus we set

$$I\,dA = (i\mu\omega)^{-1}M_z\,\ell \quad (50)$$

where M_z is the equivalent z-directed magnetic current and ℓ is the length of this equivalent element. Then (44) is rewritten

$$\Pi_z^{\circ} = \frac{M_z \ell}{4\pi i\mu\omega}\frac{e^{-\gamma r}}{R} \qquad (51)$$

We now are in the position to generalize the previous discussion by writing Maxwell's equations in the form

$$\text{curl}\,\mathbf{E} = -i\mu\omega\mathbf{H} - \mathbf{M} \qquad (52)$$

$$\text{curl}\,\mathbf{H} = (\sigma + i\varepsilon\omega)\mathbf{E} + \mathbf{J} \qquad (53)$$

where both electric and magnetic source densities **J** and **M** are allowed. As before, the electric Hertz vector satisfies (39) but, in addition, we can assert that the magnetic Hertz vector satisfies

$$(\tilde{\nabla}^2 - \gamma^2)\tilde{\Pi}^{\circ} = -\frac{\mathbf{M}}{i\mu\omega} \qquad (54)$$

Employing the previous logic, we can write the solution of (54) for an unbounded homogeneous region in the form

$$\tilde{\Pi}^{\circ} = \frac{1}{4\pi i\mu\omega}\int_V \frac{e^{-\gamma R}}{R}\mathbf{M}\,dv \qquad (55)$$

where **M** is the distribution of the impressed magnetic current density enclosed by volume V.

In the general case, for a homogeneous region where we have both source electric and source magnetic currents, **J** and **M**, respectively, the fields are obtained from

$$\mathbf{E} = (-\gamma^2 + \text{grad div})\tilde{\Pi} - i\mu\omega\,\text{curl}\,\tilde{\Pi}^{\circ} \qquad (56)$$

$$\mathbf{H} = (-\gamma^2 + \text{grad div})\tilde{\Pi}^{\circ} + (\sigma + i\varepsilon\omega)\text{curl}\,\tilde{\Pi} \qquad (57)$$

3. Final Remarks

We do not claim that our treatment of this basic subject will satisfy everyone. Also there has been some loss of rigour in the presentation and some gaps in the derivation occur. Never the less a diligent reader should have no difficulty in following the main line of thought. To follow up on the implementation of the Hertz vector in radiation, propagation and scattering, the keen student might consult the texts [1, 2, 3] where many other references are given.

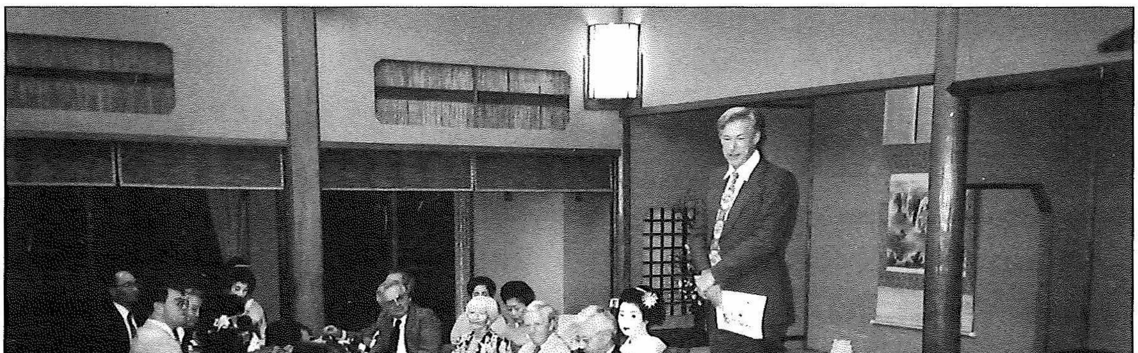
4. REFERENCES

[1] J R Wait, *Electromagnetic Wave Theory*, Harper and Row/Wiley, 1984/1987 editions out of print, 1992 preprint of revised 1992 edition available for a limited time from the author who holds the copyright.

[2] J A Stratton, *Electromagnetic Theory*, McGraw Hill 1941.

[3] A Ishimaru, *Electromagnetic Wave Propagation, Radiation and Scattering*, Prentice Hall, 1991.

[Note from Editor: The Greek font used has no bold, so the Hertzian vectors are written here as $\tilde{\Pi}$ *and* $\tilde{\Pi}^{\circ}$*]*



The old URSI Board and the Japanese Organising Committee for the XXIV General Assembly at a traditional dinner in Kyoto as guests of the Nippon Telegraph and Telephone Corporation (NTT).

The following paper is reproduced in toto (including footnote below) as a tribute to John Bolton who died in 1993 (see Bulletin, Sept, 1993, p. 3 for obituary). The Editor expresses grateful acknowledgement to A. R. Hyland, President of the Astronomical Society of Australia, for permission to republish and to John Masterson, of the CSIRO Division of Radiophysics for supplying the original photographs and graphical records.

Radio Astronomy at Dover Heights

J. G. Bolton*

In this contribution, which is an expanded version of an invited lecture at the 1982 AGM at Noosa Heads, the author recalls some of the early work in radio astronomy from Dover Heights.

1946

The Radiophysics field, which took its name from the Sydney suburb in which it was situated, Dover Heights, was an area of about 5 ha on the cliff-top south of the entrance to Sydney Harbour. It was an Australian Army Reserve and in the later years of the war had a 200 MHz coastal defence radar; the site was also used by Radiophysics staff for tests on experimental radars.

Early in 1946 J. L. Pawsey with Ruby Payne-Scott and L. L. McCready had used the Army radar there in a passive (receiver) mode and another similar installation at Collaroy, north of the harbour, to conclusively link the enhanced solar radio emission at 200 MHz with sunspots. Shortly after I joined Radiophysics in September 1946 Pawsey had attempted to confirm J. S. Hey's newly reported discovery of fluctuations in the cosmic background from the constellation of Cygnus. He was unable to repeat Hey's result.

At the suggestion of D. F. Martyn, the ionospheric physicist, I was asked to investigate the polarisation properties of the sunspot radiation. Martyn predicted that this would be predominantly circularly polarised and that in the case of bipolar spot the sense of the circular polarisation would reverse near central meridian passage. I built two Yagi aerials for 60 MHz, an alt-azimuth mounting, and a switch consisting of quarter-wavelengths of 75W cable and a 'post office' relay to reverse the sense of circular polarisation accepted by the orthogonal pair of Yagis. To these was added a modified radar receiver, an Esterline-Angus chart recorder with a microswitch operated by a cam on the chart drive; the latter provided the switching voltage to change the polarisation switch at intervals related to the chart speed selected. Bruce Slee joined me as a technical assistant and we set up the equipment at Dover Heights in November 1946. The Sun at the time was almost dormant and we made attempts to detect other astronomical bodies using the two Yagis in a parallel configuration overlooking the sea. Our local library consisted of 'Astronomy' by Russell, Dugan and Stewart and 'Norton's Star Atlas'. We used the former to hazard guesses as to which types of objects might emit copious amounts of radio emission and the latter to find the position of the brightest candidate in each class. Our efforts were unfortu-

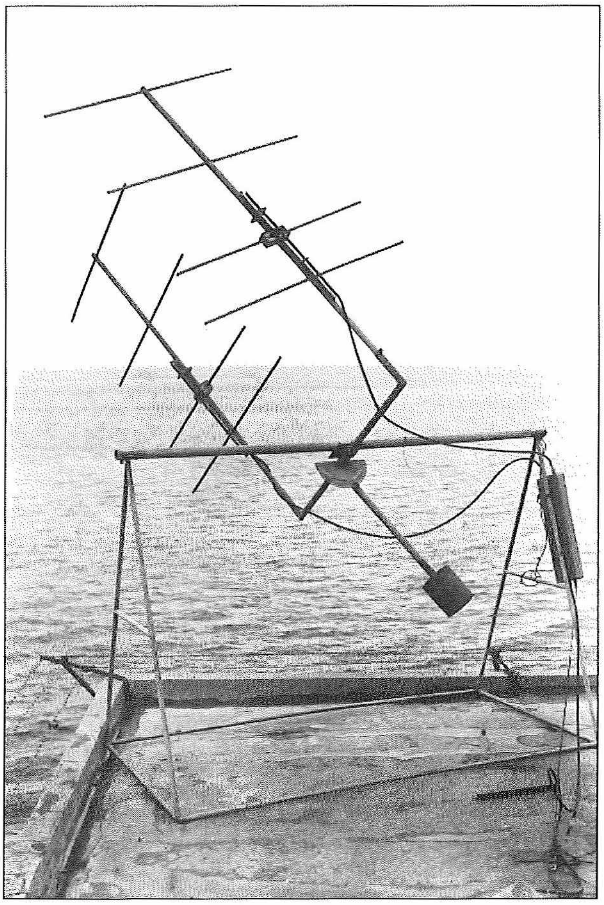


Figure 1. The 100 MHz Yagis used for work on polarization of solar radiation at Dover Heights in 1947. With the two Yagis parallel and as a sea interferometer, this aerial was used for the discovery of the first eight discrete sources.

* *The author was a distinguished member of the CSIRO Division of Radiophysics from 1946 to 1955 and from 1961 to 1981. Immediately after the period described here he was appointed Professor of Physics and Astronomy at the California Institute of Technology, where he set up the Owens Valley Radio Observatory. He returned to the Division in 1961 to become Director of the Australian National Radio Observatory. Until his retirement in 1981, he was responsible for the commissioning and subsequent operation of the Parkes radio telescope and played a major role in the decisions to build the 48-inch Schmidt telescope and the 4–m Anglo-Australian Telescope. Born in 1922, he died in his sleep on 6th July, 1993.*

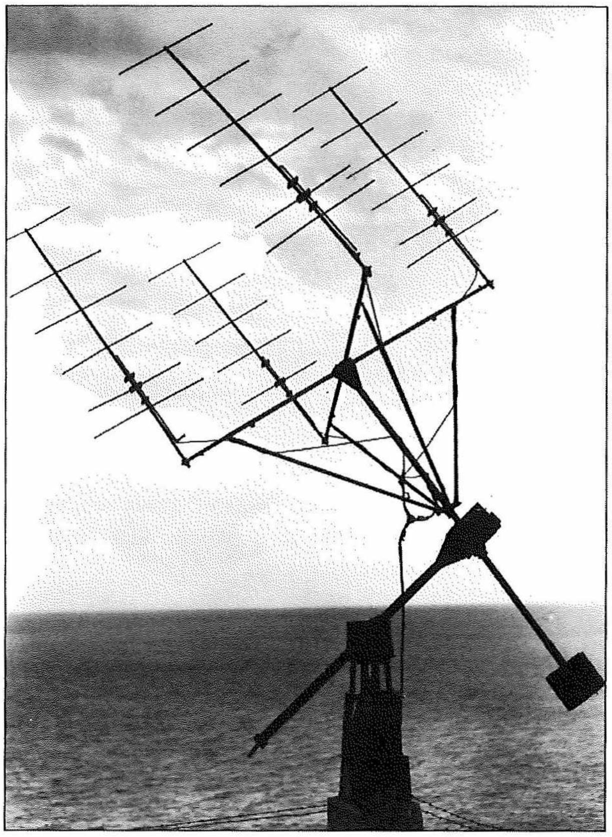


Figure 2. The 200 MHz four-Yagi array used for the study of solar radiation from Dover Heights in 1947.

nately not successful and after a week or two they were cut short by an unheralded visit from Pawsey, who noted that the aerials were not looking at the Sun. Suffice it to say that he was not amused and we were both ordered back to the Lab. Bruce was reassigned to McCready to work on receiver construction and I to assist Gordon Stanley, who was building equipment to go on an eclipse expedition to Brazil early the following year. This equipment was fairly well advanced and my job was to add polarisation and flux density calibration facilities. The eclipse observations were to be made at two frequencies, 100 and 200 MHz. The aerial systems are shown in Figures 1 and 2.

1947

Towards the end of February 1947 Pawsey came into the room where Gordon and I were working and told us that the expedition to Brazil was not to take place. He then said, 'If you can think of anything to do with all this equipment — you can have it.' As he reached the door he turned round and, almost as an afterthought, and in typical Pawsey fashion, said, 'If you can think of anything to do with Gordon Stanley — you can have him too!'. The opportunity was too good to miss; we spent the afternoon loading everything we had built on to a truck together with tools, spares and test equipment and early the following morning we were unloading into the former Army blockhouse on the edge of the cliff at Dover Heights. By 11 am we had built a one-valve super-regenerative receiver for the broadcast band, since a Test Match between England and Australia was due to start at that time. We then started to install the solar receivers. The day we had everything in working order the largest bipolar spot seen for some years appeared on the limb of the Sun; however, it was completely inactive for almost a week. Finally on a Saturday afternoon, as I unlocked the door of the blockhouse on my return from lunch, I heard the pen of one of the recorders hit the stop at the end of its travel. It was the 200 MHz recorder. I switched all three recorders from inches-per-hour to inches-per-minute and reduced the gain settings on all receivers to a minimum. Shortly afterwards the 100 MHz recorder hit its stop as the activity at 200 MHz decreased and three minutes later the 60 MHz recorder went off scale. Activity at all three frequencies ceased after about 15 min. This was the first outburst of its kind (later designated Type II by Paul Wild) to be observed. A calculation based on the time intervals and estimates of the plasma levels in the solar atmosphere at the three frequencies gave an outward velocity of ~1000 km s^{-1} and a time of flight between Sun and Earth of 26 h. The following evening a conspicuous aurora was seen from Sydney — a very rare event. The observation of the outburst was published in Nature,[1] together with data by Ruby Payne-Scott and D E Yabsley on delays of the order of 1s between two frequencies on short solar bursts (Wild's Type III).

The following day the Sun rose with a violent noise storm in progress. This storm lasted through the next solar rotation. Near central meridian passage on the second appearance in April we did see the reversal of the sense of circular polarisation as Martyn had predicted. In fact it changed several times at each frequency, owing, it was clear, to changes in the relative intensities of several radiating sources. I wrote up the observations for Martyn but the joint paper with his theoretical considerations never eventuated.

Solar activity continued at a relatively low level during May and dropped to zero in June, when Gordon and I decided to conduct an empirical search for radio sources using sea interferometers at 100 and 200 MHz. On the first night of observation a cable broke on the 200 MHz aerial and the same happened to our only soldering iron as we attempted to repair the cable. The 100 MHz equipment which was directed towards the northeastern horizon gave a sea interferometer pattern of a source in Cygnus which was clearly that

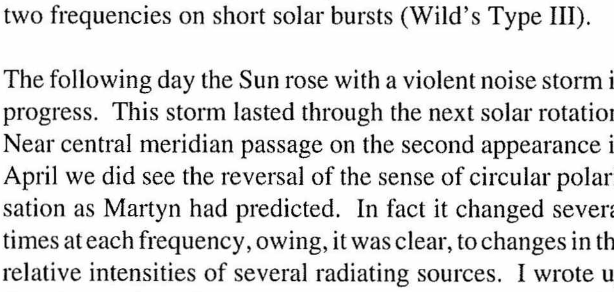


Figure 3. A typical 100 MHz sea-interferometer record of the Cygnus-A source.

previously seen by Hey. A typical pattern of this period is shown in Figure 3. The ratio of the fringe maxima to the minima, the latter an upper limit due to receiver noise, showed that the source size was less than one-eighth of the fringe separation, of 8' arc. During the next few months we determined the source spectrum between 60 and 200 MHz, made spaced-aerial observations in an attempt to determine whether the amplitude fluctuations were inherent in the source or of atmospheric origin, and measured the position of the source to the best of our ability. In the spaced-aerial observations baselines were about 20 km in a north-south direction but represented only about 2 km spatial separation because of the low observing angle of elevation. Hence there were no conclusive differences in the observations made at the two sites. For position we depended on the time of rising to give one line on the celestial sphere and the rate of change of elevation to give an intersecting line — the declination. Both quantities depended heavily on the corrections applied for refraction; had we used optical refraction corrections our positions would have been much closer to the truth than those first published. Unfortunately we used the formula devised by T. Pearcey to account for the apparent mean refraction deduced by Pawsey, Payne-Scott ad McCready from their observations of the sunspot radiation. The Pearcey formula contained a substantial ionospheric term which accounted for their erroneous assumption that radio and optical sunspot positions were coincident!

In November 1947 we wrote up what we knew of the Cygnus source[2,3] and returned to the search for others. Gordon Stanley by this time had made exhaustive investigations on the causes of short time variations in receiver noise which set the limit on our ability to detect small signals. Considerable effort was spent on the design and construction of very stable H.T. and filament power supplies. Half-discharged car batteries (i.e. after gas bubbles had ceased to break away from the plates) were an early solution; this was later superseded by 100 V stable H.T. supplies driving a number of valves in series. On 6 November 1947 we obtained a sea interference pattern of our second source, Taurus-A, later identified with the Crab nebula; this is shown in Figure 4. The difficulties confronting us at this stage from both ionospheric effects and terrestrial lightning and from instrumentation can be judged from the fact that it took almost a further three months' observation before we obtained a confirming record of Taurus-A. However, in the meantime we had detected at least two other objects, Virgo-A and Centaurus-A, and had probably evidence of another two sources. 1947 had been a vintage year!

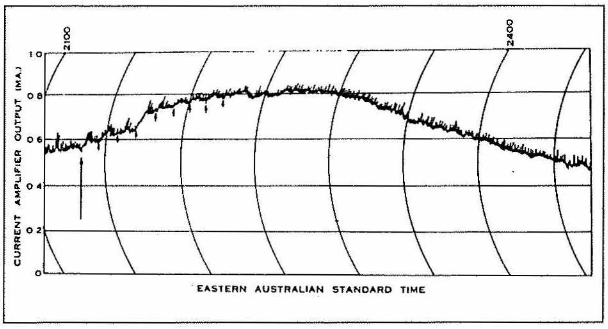


Figure 4. Discovery record of Taurus-A, the Crab nebula, obtained on 6 November 1947. Arrows mark the time of rising and interference minima.

1948

By the end of January 1948 we had evidence for at least six sources and returned to the problem of how to establish more accurate positions. Clearly the combination observations at rising and setting had great potential and Gordon and I considered the merits of potential sites in Norfolk Island, Lord Howe Island and the North Island of New Zealand before we proposed an expedition to New Zealand to E.G. ('Taffy') Bowen, the Chief of the Radiophysics Division. Taffy gave us his enthusiastic support, including arranging for assistance in logistics from the New Zealand DSIR. At the end of May an ex-Army gun-laying radar trailer containing four 100 MHz Yagis, a new 100 MHz receiver, recorders, chronometers and weather recording equipment was shipped from Sydney to Auckland. We then towed it with a borrowed NZ Army truck to the east coast site. This was on a farm 'Pakiri Hill', at an elevation of ~300 m about 10 km from the small fishing village of Leigh, 70 km northwest of Auckland. The coastline ran almost northeast to southwest and we had hoped to observe Cygnus-A over the whole semi-diurnal arc. Unfortunately the reflected signal was cut off near setting by some small islands. We spent nearly two months at Leigh, in periods of working 10 nights and then having four days' rest as tourists. Conditions were far from ideal; we had a long extension from an already overloaded power line and frequency variations caused variations in the recorder chart speed of at least 10%. The weather was sometimes appalling; on one occasion our barograph recorded a fall of 15 mm in 30 s, to be followed by a similar fall of 9 mm 10 min later. Nevertheless we obtained about 30 nights' useable data on Cygnus-A and in mid-July five observations of Taurus-A, one of which is shown in figure 5. The large number of observations was made to reduce the noise in the sidereal times of the interference minima caused by irregular refraction. One of the first discoveries we made from the observations of Cygnus-A at Leigh was that the Earth was curved! This produced incomplete interference in the first few fringes and offset to some extent the increased resolution of the more

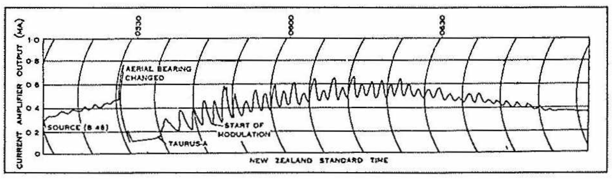


Figure 5. Sea-interference patterns of the sources 8.48 (later identified with NGC 1275) and Taurus-A obtained from Leigh, New Zealand on 13 July 1948. Evidence for a further source can be seen in the 'beat' pattern.

elevated site. The second discovery was that the amplitude variations were of atmospheric origin and not inherent in the source. Spaced-aerial observations between Leigh and Dover Heights showed almost complete correlation between solar bursts at the two sites but no correlation between source variations. The observations at Dover Heights were made by Bruce Slee, who continued to work with us after the New Zealand expedition was over. The scale size of the atmospheric irregularities responsible for the scintillations was somewhere between 2 and 2000 km. (*After we had returned to Sydney I wrote to Martin Ryle at Cambridge University, with whom I had corresponded for some time, and suggested that with the Cygnus source passing almost directly overhead he was in a better position to make more definitive investigations — perhaps in cooperation with Jodrell Bank. My first knowledge of any results was to read a joint Cambridge-Jodrell Bank Letter to Nature on my arrival in London in February 1950. At the URSI conference in Zurich that year Bernard Lovell very graciously apologised for the form of this publication, for he had not been told of our prior work!*).

At the end of August we moved to a former wartime radar station on a cliff edge some 300 m above sea level with a westerly aspect. This was near Piha, a surfing resort about 30 km north of Auckland. The diesel plant for the radar station provided a supply of electricity stable in both voltage and frequency, our receivers performed faultlessly and the weather was perfect. In three weeks we had obtained good data on four sources, Cygnus-A, Taurus-A, Centaurus-A and Virgo-A. Our first attempt to observe the last object failed — our declination was so much in error that it had set before we had started to observe! In fact the source 'changed constellations' overnight and it was clear that the New Zealand data would produce a substantial revision of all our earlier positions.

Back home in Sydney I began the long and laborious process of reducing the data. The times of minima had to be corrected for the irregularities in chart speed, and reduced to a standard date. The altitudes had to be corrected for the height of the sea deduced from interpolation of the nearest tidal recording stations. Data at rising and at setting were then combined and an iterative process used to optimise the declination of the source and a refraction correction of realistic form. The mean effect of the ionosphere was nil! The first position had within its circle of uncertainty NGC 1052 — the Crab nebula. The second based on Piha and Dover Heights data pinpointed M87 and the third on similar data NGC 5128. The position we obtained for Cygnus-A was close to but not close enough to the galaxy eventually identified by Graham Smith.

Before publication I wrote to Jan Oort, Bengt Stromgren and Rudolf Minkowski, three optical astronomers who from the literature had interest in the Crab. My letters provoked enthusiastic responses and led to subsequent cooperation — and lifelong friendships. Jan Oort wrote five pages in return on the Crab nebula and then, ever cautious, added regarding M87, 'Of course there are a lot of galaxies in the Virgo cluster.'

The identification of the Crab nebula was a turning point in my own career and for non-solar radio astronomy. Both gained respectability as far as the 'conventional' astronomers were concerned.

The success which Gordon and I had had with the expedition to New Zealand was balanced late in 1948 with the dismal failure of an attempt to observe a solar eclipse from Tasmania. Delays due to wharf strikes prevented us making any observations, though D E Yabsley and J D Murray, who shared the expedition, were successful. However, it had one consolation — I got to know the late J C Jaeger, and he suggested it might be to our mutual benefit if Kevin Westfold joined the Dover group.

1949

Early in 1949 Radiophysics workshop staff completed the first and only fully steerable 'radio telescope' to be used at

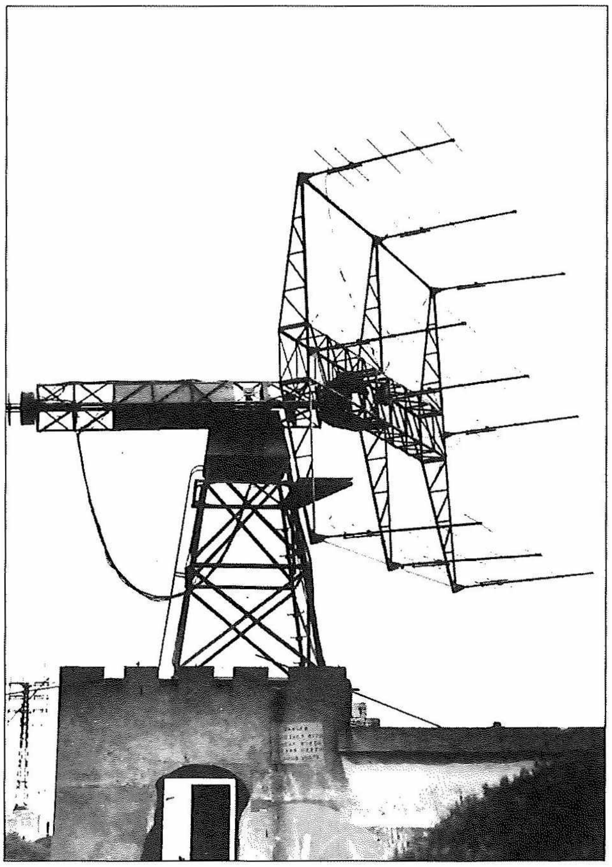


Figure 6. Nine-Yagi array at 100 MHz used for the first background-radiation survey of the Southern Hemisphere. A third axis between the polar and declination axes could be rotated to transform the mounting to an azimuth mount (as shown) for sea interferometry.

Dover Heights. It was a 9-Yagi 100 MHz array with a beamwidth of 17° mounted on an equatorial axis. It had a third axis between the polar and declination axes which, when rotated, converted the declination axis to an azimuth axis. It is shown in this configuration in Figure 6. It was used as a sea interferometer by Gordon Stanley and Bruce Slee to produce a catalogue of 22 discrete sources,[9] and also by Bruce Slee to begin a series of observations of the four strongest sources for an investigation of the seasonal and diurnal components of the scintillation phenomena. Kevin Westfold and I used the array with its mounting in the equatorial configuration to survey the background radiation from the south celestial pole to a northern limit at +30° declination. In addition to the observed contours we presented a first-order correction for the effects of the rather large aerial beam width.[8] In subsequent papers we attempted to use these data to discern the structure of the Galaxy in the plane [10] and the distribution of volume emissivity.[11] History was to reveal that these attempts were mere theoretical exercises; subsequent observations at higher resolution showed extreme complexity and fine detail in the galactic background radiation.

As Jaeger had suspected, the addition of a 'tame mathematician' to our group had its rewards — and frustrations. If only we could explain to Kevin what we knew intuitively was correct, sooner or later he would produce the formal mathematics to suit. Aerial or antenna temperature, previously jargon, became respectable, in addition to many other concepts. Kevin had time to read the current literature, amongst which was Shklovksy's original article in Russian on the 21 cm hydrogen line — which he translated. He gave the translation to Pawsey, with the suggestion that someone in Radiophysics should build some equipment to look for it — unfortunately to no avail. From Leiden in the following year we reported on the preparations in progress by the Dutch for 21 cm line equipment. Later that year F J Kerr, who was spending a year at Harvard, took me to see the equipment that Ewen and Purcell had under construction. Independently he had proposed to Pawsey that Radiophysics should take some action. Regrettably this was not to happen until after the Dutch and Americans privately communicated their detections of the H-line to Pawsey and invited a joint publication *with some southern hemisphere observations.*

Kevin and I also spent a considerable amount of time discussing what is now known as 'confusion'. I no longer recall the initial motivation for this but it was possibly a rather disappointing increase in the number of sources we catalogued with a very much better receiver and a better aerial. Signal-to-noise ratio was no longer a problem. We gave a joint colloquium at Radiophysics on 'Detectability and Discernibility'; amongst other things we had the temerity to suggest that even in the situation of infinite signal-to-noise ratio the number of sources that could be discerned (i.e. allocated a reliable flux density and position) with a simple interferometer might be somewhat less than the area of sky surveyed divided by the area of the primary aerial beam. Our conclusion was greeted with derision; it took another decade and disasters such as the 2C (Cambridge) catalogue before a figure of 50 beam areas per source was recognised as a requirement for ~95% reliability. Although we found no outside support for our conclusions it was clear to us that the way ahead involved moving to shorter wavelengths where physically possible structures could provide the needed improvement in primary beam size. The decimetre wavelength range also offered relative freedom from ionospheric scintillation and irregular refraction phenomena; however, it was a range which wartime radar had bypassed, leaving a gap in technology. Gordon Stanley was to spend most of his next ten years, first at Dover Heights and then at Caltech, on instrumentation in the decimetre wavelength range.

1950

I spent almost all of 1950 overseas in Europe and North America. I travelled to England on the second voyage of the Himalaya — six weeks at sea for £78 — albeit in the smallest cabin on the ship! I made Oxford my headquarters in Europe, as Kevin had arrived there the previous October to spend two academic years in residence, in part-qualification for a PhD. During the university vacations Kevin and I made two joint excursions to Europe and during terms I visited radio astronomy centres and observatories in the UK. I made two lengthy visits to Jodrell Bank, where visitors were most welcome. When I arrived on my first visit, Bernard Lovell handed me a dog-eared school exercise book containing the mathematical formulation of the Hanbury-Brown/Twiss intensity interferometer and asked me to see if I could find any errors. After a week of very long evenings I reported back that I could find no errors, but was at a loss for any physical understanding. The experimental proof of validity came later that year when the diameter of the Sun was measured using alternate rows of dipoles of an existing large array connected up as two interferometer elements with areas large enough to give the required signal-to-noise ratio and a separation close enough to avoid resolving the Sun.

I spent several weeks at Cambridge, where the iron curtain had already been built around the Cavendish radio astronomy activities. However, the then renegade theoretical group of Fred Hoyle, Ray Lyttleton and Herman Bondi more than made up for this. They were both hospitable and stimulating and believed in the advantages of continuing astrophysical discussions at Fenners after lunch when a county match was in progress. (Some readers may note a similarity to early days at RP in this regard!) These were the days of the beginning of nucleogenesis — the synthesis of the higher elements in stars — and the refusal of Monthly Notices to take any notice of it!

In Europe, apart from the groups at Ecole Normale Superieure in France and Goteborg in Sweden, radio astronomy began at the optical observatories. There was in general more interest in the dynamic phenomena on the Sun than in non-solar radio astronomy. It showed up even in the colloquia that we gave, where Westfold, on the mechanism of solar bursts, generally won the major applause. The exception was of course Leiden, where Jan Oort foresaw the importance of both continuum and H-line work in elucidating galactic structure.

In October I continued my journey to North America, visiting all the radio astronomy installations in Canada and the United States and the optical observatories at Yerkes, Mount Wilson, Palomar and Lick. Rudolf Minkowski was my host at Palomar and devoted many hours to my education on the possibilities of the 48-inch Schmidt and the 200-inch Hale telescopes. It was many years before I realised that even in 1950 Rudolf had decided that there was a future for radio astronomy — by 1956 his 200-inch plate collection included the reported positions of perhaps 500 radio sources.

At Dover Heights Gordon Stanley and Bruce Slee began the investigation into instrumentation at higher frequencies. They built a 16-ft parabolic mirror which was mounted initially on the gun-laying trailer of the New Zealand expedition. The telescope is shown, at a later date and on the equatorial mount, in Figure 7. Progress was very slow, particularly during the winter. A day's rain at Dover Heights was generally followed by two or three days when the runoff over the cliff edge was recycled by the updraft. In June of 1950 original rain fell on 29 days and Lake Eyre in the centre of Australia filled for the first time in this century. Nevertheless observations were obtained at several frequencies in the range between 100 and 400 MHz of the stronger sources. They were important in that they demonstrated a rapid decrease with increasing frequency in both the ionospheric scintillation and irregular refraction.

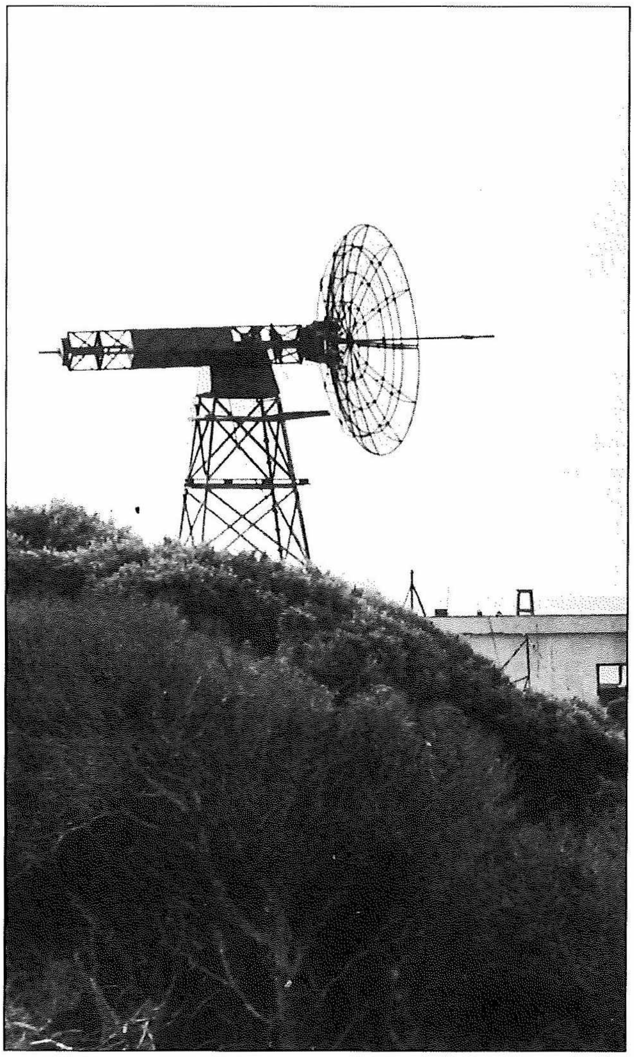


Figure 7. The 16-ft reflector built in 1960 mainly for instrument development in the decimetre wavelength range. This is part of the cover photo.

1951

1951 was a year of major changes to instrumentation at Dover Heights. The framework supporting the 9-Yagi array on the equatorial mount was dismantled. The structural components were used to build a 4x2 Yagi array on an azimuth-only mounting which had originally supported one of the World War II test aerials. It was later extended to the 6x2 array shown in figure 8; the azimuthal beamwidth was about 12° and the effective beamwidth in zenith angle somewhat less. For the sea interferometer the effect of waves combined with the output time constant of the receiver

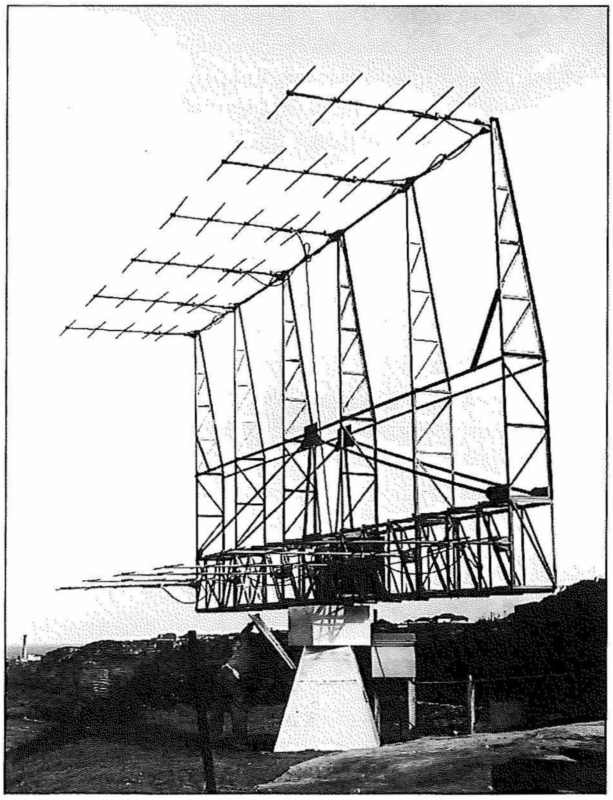


Figure 8. The final 100 Mhz sea interferometer at Dover Heights, built mainly from components of the nine-Yagi array and mounted on the azimuth turntable of a WWII radar.

reduces the amplitude of high-order fringes and thus controls the zenith angle beamwidth. The effect is similar to that of finite receiver bandwidth and output time constant. Output circuitry was developed to permit largely unattended operation of the interferometer by partly eliminating the effects of the background level changes. The detector output was fed into an integrator with a time constant of the order of 30 min — i.e. long compared with the fringe period and short compared with the time scale of background variations. The difference between the original detector output and the integrator output was recorded. An increase in contrast between fringe amplitude and background changes of about 50 was achieved, as can be seen in Figure 9a, c.

A second development was the azimuth/sea interferometer. In the 1948 observations from New Zealand, Gordon Stanley and I had set an upper limit of 8' arc on the diameter of the radio counterpart of the Crab nebula, i.e. only 50% greater than its visible extent. This upper limit was due almost entirely to the uncertainty in extrapolating the background baseline to the first of the complete interference fringes, i.e. past those affected by the curvature of the Earth. The solution we devised was to cross a sea interferometer with an azimuth interferometer of much shorter baseline. The azimuth interferometer was to be phase-switched in order to eliminate the background variation and phase-swept at a rate rapid compared with the sea interference fringes, which would form a double envelope for the azimuth fringes. We selected a site for the observations on the slope of Mount Ousley near Wollongong, 450 m above sea level, and planned to space the two elements about 70 m apart. First however we made a scale-model experiment on the cliff at Dover with the two elements only 15 m apart. To our surprise we recorded a large number of sources with the azimuth fringe system which did not appear on the sea interferometer. Amongst those which had to be greater than 1/2° to be resolved by the sea interferometer were extended sources associated with Centaurus A (NGC 5128), Fornax-A (NGC 1316) and Puppis-A. The description and position of the Puppis-A source was sent to Baade and Minkowski, who were able to identify it on a 48-inch Schmidt plate as a supernova remnant. A typical azimuth/sea interferometer observation is shown in figure 9b. The investigation of the extended sources[15] was given priority over the intended measurements of the Crab Nebula; the project was finally cancelled when special interferometers for measurement of the sizes of the major sources were built at Jodrell Bank and Cambridge and by B Y Mills in Sydney.

The final development in 1951 was the construction of a 72-

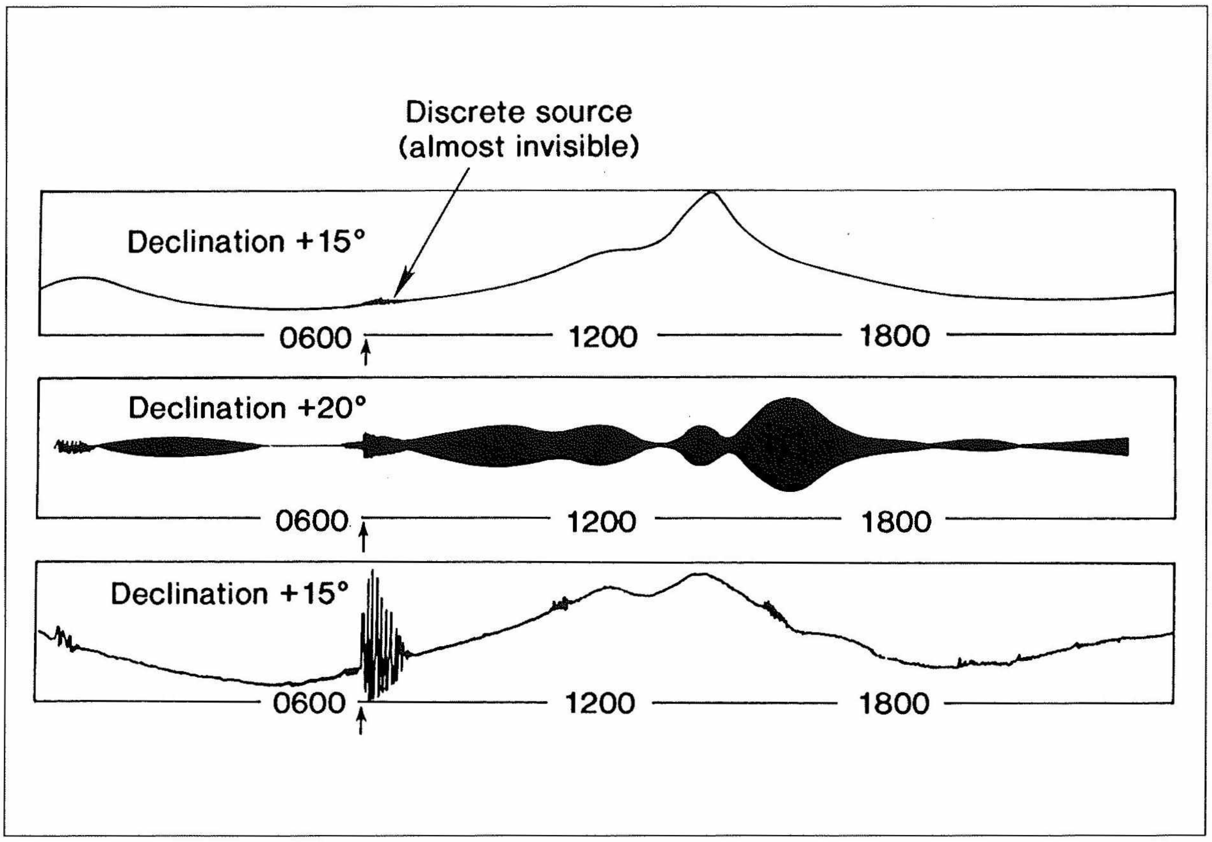


Figure 9. (a: top panel) Twenty-four-hour record of the galactic background radiation and discrete sources seen by the final 100 MHz sea interferometer.
(b: middle panel) The output of the azimuth/sea interferometer at approximately the same azimuth as in (a) or (c).
(c: bottom panel) The same data as in (a) after processing to largely remove the effects of the background radiation. The strongest sea-interference patterns in all three figures are Taurus-A (the Crab nebula) and Virgo-A (M87), shown arrowed.

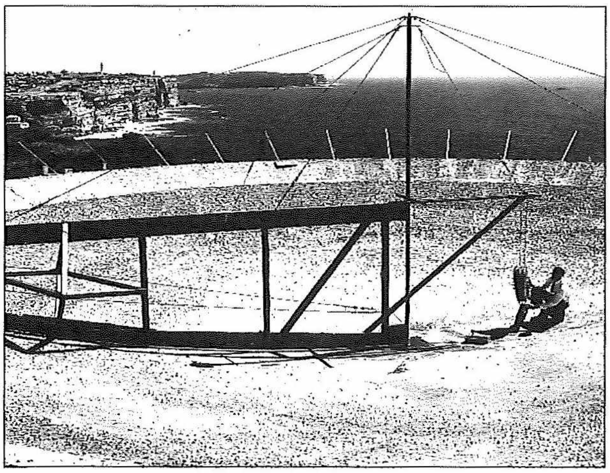


Figure 10. The concrete surface is added to the original hole-in-the-ground. The rotating template was used to position formwork for the concrete and also to finish the surface.

ft hole-in-the-ground parabolic reflector. Subconsciously this instrument probably followed the 220-ft reflector built by Lovell for radar detection of cosmic ray showers and used as a passive instrument to great advantage by Hanbury-Brown and Hazard. The major part of Lovell's reflector was supported on posts above the ground with only the area near the vertex excavated. The Dover Heights reflector was mainly excavated, with the spoil being used to build the outer rim. Bruce Slee and I did most of the excavation, Kevin Westfold joined in after his return from Oxford, and Gordon Stanley trucked several loads of ash from the Bunnerong powerhouse each week to stabilise the sand out of which it was formed. Finally a reflecting surface was made from obsolete steel strips formerly used for binding packing cases. The construction site for the 72-ft reflector was not visible from the official working area of the Dover Heights station; the construction was carried out in our own time and in secrecy. Only Taffy Bowen was taken to see it when it was sufficiently advanced that its purpose was obvious. He both approved of it unofficially and agreed to say nothing about it until it was operational.

Figure 11. The complete 80-ft reflector showing the addition of the wire mesh surface, the feed mast and the housing for the second stages of the reciever at the vortex.

1952

Early in 1952 we completed a survey of the galactic radiation between declinations –20° and –47° at 160 MHz with the 72-ft hole-in-the-ground. The difference between this survey and the earlier 100 MHz 9-Yagi results was striking. A three-to-one reduction in aerial beamwidth had produced a three-to-one reduction in the apparent half-width of the galactic radiation in the region near the galactic centre. Joe Pawsey was also impressed with the results and had no hesitation in agreeing to our suggestion that we should attempt a further factor of three in resolution. To achieve this we would have to operate at a much higher frequency and increase the diameter of the reflector. The hole-in-the-ground was turned into an improved mirror by adding a half-inch wire mesh on top of a concrete surface over the existing ash and sand base. Figure 10 shows this operation almost complete, and — the heart of the modus operandi — a giant template. The template was used to set annular timber formwork for the successive rings of each concrete pour and as a 'screed' for finishing the surface. Short lengths of galvanised wire were left protruding from the concrete in order to secure the final wire-mesh surface. Aluminium tubes and annular tension wires provided a base for an extension of the diameter to 80 feet.

Figure 11 shows the completed reflector together with its feed and mast. Atop the mast were the r.f. switch and front end of the receiver — three 6J4's as grounded grids in cascade with a noise temperature of about 1400 K at 400 MHz. The switch was a parallel plate cavity between feed and receiver operated by a rotating sector of perspex coated with the thin aluminium foil found in cigarette packs of that era. A major problem with the switch was a gradual deformation of the perspex due to relieving of inbuilt stresses and consequent contact with the sides of the slit in the cavity. Every second or third day the mast had to be lowered, the switch dismantled and the perspex immersed in boiling water in the tea urn for half-an-hour. The perspex was then cooled between flat steel plates in a vice, recoated with aluminium foil and the whole system restored. (To forestall two obvious questions, the deformation under spinning was not unique to one piece of perspex, and its replacement with a dynamically balanced metal sector plus heavier motor drive was too much of a weight penalty.)

Dick McGee, who had replaced Kevin Westfold at the beginning of the year, assumed responsibility for the 400 MHz survey, rapidly becoming high skilled in the switch repair operation. Another hazard that Dick faced in the winter of 1953 was to plunge into several feet of icy cold water to remove the debris which occasionally was to block the 'self-starting' syphon which drained the mirror. To cope with such eventualities the second states of the receiver were 'moored' in a waterproof box which went up and down with the tide in the vertical enclosure at the vertex shown in Figure 11.

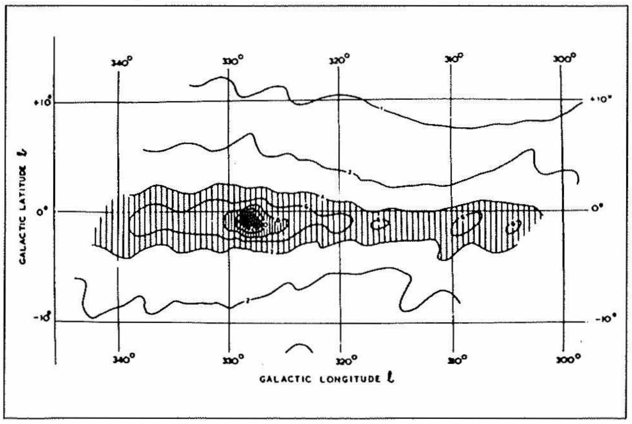


Figure 12. The region near the direction of the galactic centre as seen by the resurfaced 80-ft reflector at 400 MHz in 'old' galactic coordinates.

In 1952 the programme of monitoring the scintillations of the four major sources which Bruce Slee had begun four years earlier was terminated. Analysis of about 2000 observations showed a correlation with sporadic E (as opposed to spread F for observations of sources near vertical incidence). Difference between data for the individual sources could be ascribed to variations in the structure of the irregularities with geomagnetic latitude and the effects of ionospheric winds.[13]

1953 and Postscript

Early in 1953 the sea-interferometer survey with the 12-Yagi array was completed and the final 100 MHz catalogue of 104 sources from Dover Heights compiled.[16] It was the first survey to show an excess of faint radio sources, which was due largely, in retrospect, to the effects of confusion.

Our major interest however centred on the early results at 400 MHz from the 80-ft reflector. In the region near the galactic centre the radiation was highly concentrated in a narrow strip only a few degrees wide (Figure 12). If the radio emission could be used to delineate the galactic plane, then it clearly lay about 1.5° south of $b = 0°$ in the old coordinate system. The most dominant feature was the source Sagittarius-A, which to our 2° beam appeared almost unresolved. This source, although it had been seen at higher frequencies, had not been observed at this resolution previously. Partly because of its location with respect to the more diffuse contours and its latitude and partly by analogy with Baade's then recently discovered semi-stellar nucleus in M31, Dick McGee and I suggested that it was the nucleus of our own galaxy. Three years later the IAU ratified the view, making the source position the zero of longitude in the new system of galactic coordinates.

I left Dover Heights towards the middle of 1953 at Taffy Bowen's suggestion — first to work in cloud physics and then in January 1955 to go to the California Institute of Technology to build the Owens Valley Observatory. For some months previously Gordon Stanley and I had been considering our next major move. We had three possibilities in mind. One was to build a second hold-in-the-ground to form an interferometer with the first. The second, inspired by Taffy, was to build two rolling barrels — parabolic cylinders inside circular cylinders — to form an interferometer. The third and my own choice was to build a large sea interferometer for use at 400 MHz. This would have consisted of a cylindrical paraboloid 20 ft high and 200 ft long with a focal length of about 150 ft fed by a vertical stack of dipoles. The construction of the mirror would have been similar to the fence round a tennis court and would have been rebuilt for each 40° of azimuth; the 40° interval covered by moving the dipole stack. The primary beamwidth would have been 1° in azimuth and the interference fringes 15' arc apart. Unfortunately it was not to be financed — the Mills Cross had won the day.

Dick McGee continued to work on the 400 MHz survey and when this was finished Gordon Stanley and a Fullbright Fellow from MIT, Robert Price, used the 80-ft telescope in an attempt to detect the 327 MHz line of deuterium in absorption against the source at the galactic centre. Their negative result[20] was not published until some Russian observers claimed a positive detection well above their upper limit. Bruce Slee joined the group on the Mills Cross in mid-1954 but continued some work on apparent variations in the intensity of Hydra-A[19] until the end of 1954, when the Dover Heights field station finally closed.

I am sure that my colleagues from the Dover Heights era would wish to join me in thanking the then staff of the Radiophysics workshops, most of whom have long since retired, for their efforts on our behalf — in particular Bill Thompson, who bore the brunt of most of the outdoor construction work at Dover Heights itself.

The following list of references relating to work done at Dover Heights is arranged in chronological order (of publication). Some references are mentioned specifically in the text.

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Analytical and Numerical Methods in Electromagnetic Wave Theory

edited by M Hashimoto, M Idemen and O A Tretyakov, published by Science House Co Ltd, Shindo Bldg, 1-4-17 Higashi-Tabata, Kita-ku, Tokyo 114, Japan, ISBN: 4-915572-54-4 C3055, 1993, US$177 incl. air postage (572 pages, 182 × 257 mm).

The papers in this paperbound collection are based on presentations at the International Seminar/Workshop on the subject of the book title, which was held at Cukurova University in Adana, Turkey, June 3-7, 1991. The aim of the seminar was to consider recent developments in the subject. Besides the editors, contributions were from A Buyuksoy (Istanbul), K Kobyashi (Chuo Univ, Japan), E Luneberg (Germany), A I Nosich (Kharkov), Y Okuno (Kumamoto, Japan), A Serbest (Adana Turkey), H Shirai (Japan), E Veliev (Kharkov) and V Veremy (Kharkov). Chapter 1 deals with the geometrical theory of guided waves based on the idea of wave-normal rays. Chapter 2 treats inverse scattering problems related to cylindrical bodies including cases where the body is located in a bounded host medium. Chapter 3 gives a general theory for non-linear phenomena such as unstable oscillations and/or fluctuations in non-linear media. Chapter 4 describes approximate Wiener-Hopf problems which are suitable for numerical work. Comparisons are made with "rigorous" asymptotics. Chapter 5 has more material on the modified Weiner-Hopf technique with emphasis on strip/slip problems. Chapter 6 follows up with specific applications to diffraction by idealized structures. Chapter 7 discusses three related function-theoretic techniques and demonstrates their equivalence. Chapter 8 deals with transient problems choosing idealized geometries. Chapters 9, 10 and 11 cover a variety of numerical methods including hybrid techniques and selected graphical presentations are shown.

The book contains many developments in the analytical and related numerical schemes which are not available in the Western journal or book literature. I would recommend the book to active workers in the field. The price is a bit high particularly since the book has been prepared in $\TeX$ by the individual authors. The general style of the writing is excellent which suggests the editing was carefully done.

James R Wait
Review Editor

Reciprocity, Spatial Mapping and Time Reversal in Electromagnetics.

by C. Altman and K. Suchy. Kluwer Academic Publishers, Dordrecht, Holland, 1991, ISBN 0-7923-1339-9. Hardbound, price Dfl185, US$99, UK£62.

According to the authors, the book under review is a result of research by the authors during the last two decades. The original topic was electromagnetic wave propagation in plane-stratified magnetoplasmas like the ionosphere, but the material has been generalised during the years to cover most general linear media. The book discusses the reciprocity principle in such media and its relation to time and space transformations. Historically, there have been two main approaches to the reciprocity principle: one, originally due to Lorentz (1896), dealing with fields due to sources in two physical spaces filled with two conjugate media, the other dealing with certain symmetries of scattering matrices for plane-wave incidence. The present authors have studied the connection and generalisations of the two approaches and the book under review can be seen as a logical and systematic presentation of that material.

The text is given in seven chapters. In Chapter 1, wave propagation in the cold magnetoplasma is discussed as a concrete example of a medium for which the abstract theories can be applied. A compilation of techniques in common use for treating electromagnetic-wave propagation in a plane-stratified magnetoplasma, typically the ionosphere, is given together with a discussion on different numerical methods. This chapter appears a convenient source of material useful for practical computation with references to original articles.

Chapters 2 and 3 consider reciprocity theorems or scattering theorems in **k** space and their generalisations. The first version of such theorems was formulated by Budden in 1954, relating the reflection coefficients of two plane waves incident on a plane-stratified magnetoplasma at two symmetrical angles (two conjugate problems). This and other scattering theorems given by various authors for plane waves in a source-free medium are rederived in these two chapters in a systematic and coherent manner.

Chapter 4 discusses the Lorentz reciprocity theorem for sources and their fields in different media. To have the reciprocity theorem satisfied, the second sources must exist in what is called the Lorentz-adjoint medium, obtained through certain transformations in space and time from the original medium.

Chapter 5 associates the Lorentz reciprocity theorem of Chapter 4 and scattering theorems of Chapters 2 and 3 by developing the Green functions in the two conjugate, or Lorentz-adjoint, media. Expressing the Green dyadics in terms of their plane-wave expansions, the reciprocity theorems in **k** space are seen to lead to the Lorentz reciprocity theorem in the physical space and, thus, the two branches of research are united.

Chapters 6 and 7 consider, respectively, space and time transformations or mappings of electromagnetic system of sources, fields and media. It is shown that reversing the time in the system of Maxwell equations leads to the Lorentz-adjoint system provided the time reversion is not extended to processes involving losses, which means that the time-reversed system does not create energy.

Reading the text requires some alertness but is rewarding. Perhaps the most annoying point for a casual reader like the present one, familiar with the Gibbsian vector and dyadic notation, is the missing of the dot in the inner product of a dyadic and a vector: instead of $(\mathbf{ab})\cdot\mathbf{c}$ and $\overline{\overline{A}}\cdot\mathbf{c}$ as in the Gibbsian notation, the authors write in matrix style $(\mathbf{ab}^T)\mathbf{c}$ and $A\mathbf{c}$. On the other hand, the cross product and double-dot product with a dyadic are adopted in the Gibbsian form like $\mathbf{c}\times\overline{\overline{I}}$ and $\overline{\overline{A}}:\mathbf{ab}$ However, the dyadics are printed clearly in boldface so there is no place for misunderstanding.

The book is suitable for scientists working on basic electromagnetic theory and their applications to wave propagation in layered magnetoplasmas or other bi-anisotropic media. Knowledge on the rules of reciprocity and spatial transformations will save work in analysis if solutions for new problems can be recovered from old problems with known solutions. The book can also be used as material in a course on electromagnetic theory for doctoral students, especially if there is some background in magnetoplasmas.

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Note from the Review Editor :
If you are interested and willing to review books for the Radioscientist, send me a complete description of the item and the name (and address if possible) of the publisher. Publication dates should be 1993 or 1994. Of course, you may keep the book after you have fulfilled your commitment.

Mail reply to: **James R. Wait, 2210 East Waverly, Tucson AZ 85719-3848, USA.**

Ultra-Wideband, Short-Pulse Electromagnetics (UWB-SP)

edited by H L Bertoni, L Carin and L B Felsen. Plenum Press, New York, ISBN 0-3-6-44530-1, 1993. $115.00 US and Canada, 20% higher elsewhere, 542 pages, cardboard bound.

This author-prepared document is the "proceedings" of a conference held in Brooklyn, NY USA in October 1992. A previous conference, under different auspices was held in Los Alamos in March 1990, on the same topic (see review in *the Radioscientist*, vol3, No2, pg 49, 1992). The Brooklyn organizers chose a wide range of invited speakers who were described as "leading scientists from universities, government and industry, who are active in various areas of UWB-SP electromagnetics". The central theme of the conference was to address the controversial issue of whether one should approach the problem from the standpoint of the time domain or resort to the more classical procedure of dealing first with the frequency domain followed by a Fourier synthesis to obtain the transient response. Apparently the "debate", if it can still be called such, is laced with political content of various DOD (US Dept of Defence) agencies. Indeed, the Brooklyn conference followed the convening of a DOD review on the subject. Not surprisingly, the findings of this panel of experts was not to be found in the publication under review here. (Maybe the nine blank pages at the end of the "book" are reserved for this purpose!) Also there was a workshop on "Open questions and future trends" at the end of the conference with "strong participation from a lively audience". Unfortunately a record of the discussions also did not appear here.

But let us continue the review of the published proceedings. The specific topics, as described by Professor Leo Felsen are: Pulse Generation and Detection, Broadband Electronic Systems and Components, Antennas and Arrays, Pulse Propagation and Guidance, Scattering Theory and Computation and Signal Processing Techniques. There were 66 papers presented either orally or in poster sessions. With this format there were no conflicting sessions. For the most part the authors came from the US but there were also participants from the UK, Italy, Canada, Sweden, Israel, and Germany. Most of the printed papers are clearly written and the illustrations are very good. However, it is a pity that few authors included an abstract. Also cross referencing between individual papers was non-existent with possibly one or two exceptions. It would have been nice if the three editors had teamed up to write an overall summarizing paper. No doubt, after the dust settles, we will see a self-contained account in the open refereed literature. In the meantime, people will find the present published Proceedings a valuable source of current advances in the field. Finally, it is worth noting that a follow-on conference on the same topic is to be held April 5-7, 1994 in Brooklyn and the conference chairpersons are Professors L Carin, L B Felsen and S U Pillai at the Weber Research Institute, Six Metrotech Center. (Contact FAX 718 260 3906 – Attn: Prof Carin.) The stated purpose of this sequel is to assess further developments and to place emphasis on UWB/SP systems and time domain processing. A good fraction of the invited speakers are active in the URSI community so no doubt there will be some spill over in the journal (*RADIO SCIENCE*) in the next year or two – from both Brooklyn conferences.

Some selected highlights (of the 1993 UWB-SP Conference Proceedings):

- A system for generating well collimated beams of freely propagating femtosec. THz pulses with a signal to noise ratio of better than 1000 (Katzenellenbogen and Grischkowsky).
- Performing scattering measurements in the time domain using photoconductively switched planar antennas (Carin).
- Generation of the first sub-picosecond voltage shock waves using non-linear transmission lines fabricated on GaAs immersed in liquid nitrogen (Van Der Weide et al).
- Formation of ultra-short solitons on periodic Schottky contact translines and the generation of picosecond pulses (Dragoman et al).
- Description of the Monterey impulse scattering laboratory (Morgan).
- UWB scattering measurements on targets showing effects of resonance, travelling waves, and creeping waves (Madonna et al).
- The Sandia Plasma Switched UWB Impulse Program Facility (Clark et al).
- A prototype impulse radio communication system demonstrated for a range in excess of 7 km (Withington and Fullerton).
- Discussion of the UWB clustered cavity Klystron (Siambis and Symons).
- Summary of recent work on IRAs (Impulse Radiating Antennas) and comparison with TEM horns (Baum).
- Accurate modelling of SP antennas with reference to optimizing conical monopole structures (Maloney and Smith).
- Design of multiple-polarization UWB antennas (Wicks and Antonik).
- Obtaining low cross polarization from UWB-SP printed antennas over wide beam angles (Mohanty and Das).
- Design of transient lenses for transmission lines and antennas including the possibility of getting exact solutions (Baum and Stone).
- Description of UWB-SP propagation in linear dispersive media and the role played by the saddle points of the complex phase function, the initial pulse envelope and the pulse carrier (Oughstun et al).
- Analysis of pulsed beams or highly localized space-time wave packets that propagate along ray trajectories (Heyman).
- The exploitation of soliton propagation to overcome adverse medium dispersion and related non-linear effects (Arnold).
- Comparison of UWB pulse and single frequency transmission into lossy media showing better penetration of the pulses (Li et al).
- An analytical continuation scheme for determining UWB medium parameters from only low and high frequency measurements (Alexopoulos and Diaz).

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***Remark by Review Editor**: The descriptor "Proceedings" is somewhat of a misnomer since the individual papers were written before the conference and no material from the discussions were included. Many recent "non-books" such as the NATO conference documents seem to fall in this category. But publishers still have customers.*

Erratum

We regret that the line below in bold was omitted in the review published in *the Radioscientist*, **4**, p.67, and partly reproduced here.

The Electrical Engineering Handbook edited by Richard C Dorf, CRC Press, Boca Raton, Florida, 1993, 2662 pages, ISBN 0-8493-0185, US price $89.95.

As indicated in the preface, this massive document, in a single binding, is intended to provide a ready reference for the practicing engineer in industry, government and academia. The book is divided into twelve sections which encompass the whole field of electrical engineering. The ultimate goal is to **provide the most up-to-date information in fields such as: circuits,** signal processing, electronics, energy devices, systems, telecommunications, computers, and biomedical engineering. There are a total of 109 chapters averaging about 25 pages each but ....

Second Nobel Prize for Pulsar Research

After little more than one decade Radio Science has again been honoured with the highest award in science, the Nobel prize in Physics. In 1978 A. Penzias and R. Wilson from Bell Labs received their prize for their landmark discovery of the 3K microwave radiation in the Universe, the last breath left over from the initial fireball, the Big Bang. Their prize honoured the high technical standard of radio science in the world. Many in the physics community may have expected that this year's prize would be given to the extension of microwave background research and the presumable discovery of the first indication of large-scale microwave anisotropy in the Universe by the COBE team. However, the Nobel committee decided differently, probably because more confirmation must be accumulated before the COBE result can be considered true and a safe achievement of observational radio science. The committee may as well have decided to wait for groundbased observational support of the COBE stuff. Observations on the ground have been performed for many years in Antarctica and are now close to becoming conclusive. Ignoring these effort would be rather unfair when honouring only the COBE team for first firing. So the noble self restriction of the Nobel committee also demonstrates its aristocratic attitude.

The greater was the surprise of its choice of this year's Nobel laureates to be in the same field of research. Giving the prize to Joseph H. Taylor and Russell A. Hulst from Princeton not only honours radio science but also radio astronomy. In the words of the Nobel committee the prize has been awarded for the discovery of a binary pulsar which has "opened up new possibilities for the study of gravitation". The pulsar under question is the binary system PSRT B1913+16, where the numbers refer to its position on the northern sky. It was discovered by them in 1974 when Hulst was a graduate student of Taylor at Amherst, Massachusetts. At this time pulsar research was quite young and had in 1974 just been awarded a Nobel prize to Anthony Hewish for the discovery of pulsars in 1967 by Jocelyn Bell and him. Hulst had been sent by Taylor to the Arecibo large radio telescope to look for pulsars in the registrations. The above unknown pulsar he found was modulated in its radio signals. So Hulst called up Taylor who immediately came down to Arecibo where they determined the modulation frequency and attributed it to modulation of the radiation due to a companion star. They were able to determine its mass and distance from the pulsar. Fortunately the star was close enough to produce a significant modulation of the signal. Hulst subsequently, after finishing his PhD, left radio astronomy and went to the Plasma Physics Laboratory in Princeton. Taylor, ultimately also moving to Princeton, further analysed the data for better timing the pulsar period. For this he had to eliminate all possible disturbances. Since the stars were very close together, one a solar radius apart, the residual variation Taylor detected could have been caused by excitation of gravitational waves. Taylor calculated their effect and was able to show that when subtracting it from the signal nothing remained but white noise. For the first time existence of gravitational waves was unambiguously demonstrated. Only since then one can believe in the prediction of Einstein's General Relativity that gravitational waves are not a fiction but physical reality. I vividly remember the great moment when Taylor first presented his result at the Texas Conference in Munich in 1978. I immediately noted to my neighbour, Joachim Trumper, Director of the Max-Planck Institute of Extraterrestrial Physics and the "father" of the now so successful X-ray satellite ROSAT, that this was a seminal discovery and certainly the next Nobel prize. He nodded, but we were both wrong — until now, when we already had forgotten about this event. It was a great surprise blended with satisfaction that the Nobel committee has ultimately turned to honour this great work bringing it to the attention of all the scientific and possibly also the non-scientific community.

The delivery of this year's Nobel prize to both Taylor and his former graduate student Hulst, has a certain special but somehow sad flavour. It is perfectly right because Hulst discovered the binary pulsar which later Taylor was able to prove the reality of gravitational waves with. But it also looks like a late correction of an obvious earlier omission made by the Nobel committee in just the same field when it failed to honour Jocelyn Bell, also a graduate student at the time, for the discovery of pulsars — a well known and famous story.

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Bianisotropics'93

— an international seminar on the electrodynamics of chiral and bianisotropics was held at the University of Gomel in the Republic of Belarus, on 12-14 October, 1993. Please contact Ari Sihvola (Associate Editor) for the Proceedings. The follow-up workshop will be held in Perigueux, France, on 18-20 May 1994. Information: Chiral'94, PIOM, ENSCPB, 351 Cours de la Liberation, 33405 Talence Cedex, France.

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Looped Demonstrations on Global Dynamics of the Ionosphere and Optimum Regimes for Ionospheric Communications

A software demonstration prepared by the Russian Academy of Sciences. Availability is given below.

A package of seven computer film loops has been prepared to demonstrate different aspects involved in supplying reliable communication links. There are three groups of demonstrations: propagation predictions (2 examples), antennas (2 examples) and ionospheric modelling (3 examples). All the demonstrations are in the form of films, a powerful method for illustrating the examples modelled. The software is the product of a long term effort at IZMIRAN.

The software is supplied on two 3.5 inch disks to run on a PC under DOS with a VGA screen and, preferably, a 386 processor with 4MB of free RAM. Installation is straightforward and creates a series of directories in the root directory under the directory name demo. These take up roughly 5 MB of space. The demonstrations can be run as a group, using the two supplied batch programs, or separately. There are two language versions: English and Russian. Each of the three groups of demonstrations is discussed next.

The antenna demonstration is a well planned display showing the changes in the polar diagram for two antennas as they are used for a stepped range of frequencies. This is a good educational display showing clearly how frequency affects antenna usage.

The ionospheric modelling displays use the International Reference Ionosphere (IRI) and topside data from the Intercosmos-19 ionospheric sounder to illustrate how the global ionosphere changes over a day. Each is worth commenting on. Each frame of the Intercosmos-19 display shows the ionospheric cross-section in the satellite orbit plane. A full day of orbits make up the complete demonstration. This is an excellent display of the diurnal and longitudinal changes in the ionosphere. Although the presentation is possibly unsuitable for scientific study, it is valuable for visualisation purposes.

The second demonstration in this group matches the topside observations to the IRI bottomside to produce a complete picture in the global ionosphere. The third demonstration repeats this using only the IRI outputs, showing a strong contrast in detail between model and data.

The final group of two demonstrations illustrates examples of the IRI used to make propagation predictions. There are a wide variety of possible ways this information can be displayed and for some these displays will be less impressive than the others collected together here. Clearly, the wide variety of possible options for presenting propagation predictions makes it difficult to satisfy everyone. However, the general principal of using a time dimension, in the form of a repeating film loop, to illustrate the effects of the ionosphere on propagation is a good educational device and some of this potential is illustrated here.

The main purpose of the package is to offer examples of the type of applications that have been developed, and can be developed, at IZMIRAN. The packages developed to date can be generalised to other applications. In this review the demonstrations have been considered at three levels: as demonstrations of a wider range of possible software, as examples of visualisation and as a set of educational displays in their own right. This group of demonstrations is worth considering in any of these roles.

To date there has been a limited distribution of the software, but copies can be obtained from:

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Geophysical Centre
Molodezhnaya 3
Moscow 117296
RUSSIA.
Internet email: SGC@adonis.iasnet.com

To obtain copies send four blank 1.4MB 3.5 inch disks to Dr Feldstein and two disks will be returned containing the software. The additional disks will offset postage costs.

Phil Wilkinson
Ionospheric Prediction Service
Sydney, Australia.

Editor: The essential part of this, namely the instructions on where and how to obtain copies of the demo, was inadvertently omitted in the version published in the June issue (Radioscientist **4**, *p.55). It is therefore printed here in full with our apologies.*