The Radio Science Bulletin

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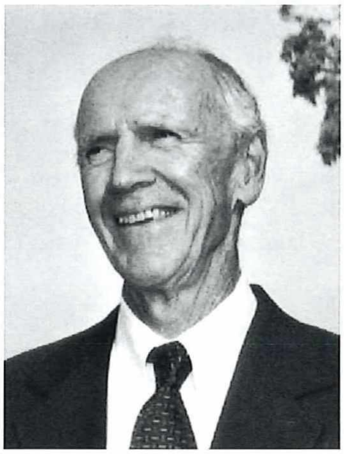
INTERNATIONAL
UNION OF
RADIO SCIENCE

UNION
RADIO-SCIENTIFIQUE
INTERNATIONALE

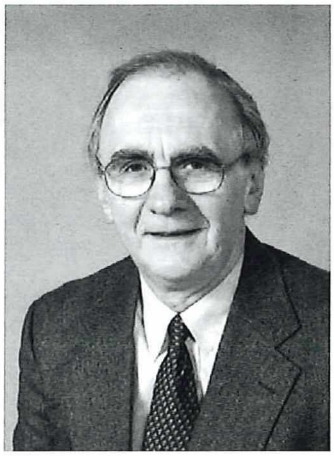
U.R.S.I.

2002 Awardees

Prof. A.T. de Hoop

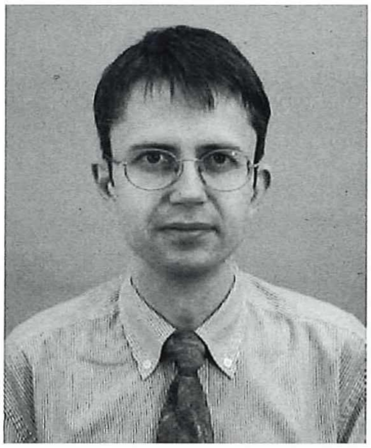


Prof. D. Carpenter



Dr. R.A. Greenwald

Prof. S. Haykin



Prof. F. Olyslager

No 301
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St.-Pietersnieuwstraat 41, B-9000 Gent (Belgium)

Contents

Front cover: At the XXVIIth URSI General Assembly in Maastricht (The Netherlands) this August, the scientists whose pictures feature on the front cover will be presented with the URSI Awards. For more information, please *turn to page 9 of this Bulletin.*

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The International Union of Radio Science (URSI) is a foundation Union (1919) of the International Council of Scientific Unions as direct and immediate successor of the Commission Internationale de Télégraphie Sans Fil which dates from 1913.

Editorial

URSI Has a New Web Address!

Thanks to some quick action by Paul Lagasse and the URSI Secretariat, URSI's Web URL is now **www.ursi.org** – exactly what it should be! Visit the new address and you'll find a wealth of information about URSI, URSI activities, reports from Member Committees and Commissions, and information on the General Assembly and other URSI conferences. Our Web Master, Inge Heleu, has done an excellent job of organizing the material and keeping it up-to-date: go take a look.

The XXVIIth General Assembly

If you haven't made plans to attend the Maastricht General Assembly, you really should do so now! It is going to be a great technical meeting: the preliminary program is available *now* on the Web via a link from the General Assembly Web page at http://www.URSI-GA2002.nl/. This is *the* once-every-three-year opportunity for radio scientists to interact with colleagues in their technical area, through the open technical sessions and the open Commission business meetings. It is also a great location from which to start or end a holiday in Europe. Maastricht is centrally located, an easy train ride or drive from many wonderful vacation locations. You should really plan on going.

What's in this Issue

Several triennia ago, the URSI Council mandated that General Lectures would be a part of every General Assembly. These are lectures on radio science that are intended for the broadest of audiences. They should be of interest and value not only to radio scientists, but also of interest to the general public. There will be three such General Lectures at the Maastricht General Assembly. Michael Repacholi's "Assessment of the Health Effects of EMF Exposure" is one, and we have a paper based on his lecture in this issue. The World Health Organization (WHO) has an International EMF Project underway. The purposes of this project include assessing the current state of knowledge regarding the effects of EMF (electromagnetic field) exposure on humans; identifying areas where knowledge is lacking; promoting needed research to funding agencies; providing advice to national authorities on how best to manage EMF issues; and providing assessments leading to the development of an international consensus on exposure guidelines. This is a complex and often controversial area. This paper does an excellent job of reviewing the current status of this work, and the state of knowledge of the effects of EMF exposure. It's a topic that should be of interest and importance to all radio scientists.

Radio astronomy is at a critical juncture as a field of radio science. On the one hand, technological advances have made it possible to detect incredibly faint signals. This has expanded the number of potentially observable sources tremendously; it has also made it possible to "look backwards in time" to a remarkable degree, enabling remarkable new discoveries about the formation of the Universe and its ongoing processes. On the other hand, such observational sensitivity, combined with the proliferation of radio emissions and the demand for spectrum that have become an inherent part of our world, threaten the very existence of the radio-astronomy field. It is against this background that Masatoshi Ohishi is calling for a united Asia-Pacific radio astronomy front, in his paper in this issue. His paper examines and explains both the scientific and the political bases for the problems facing radio astronomy. The role of the International Telecommunications Union (ITU), in spectrum allocation and in rule-making regarding radio interference, is central to this challenge. The paper does a very nice job of explaining this complex role, and of identifying how radio scientists may be successful in literally saving radio astronomy. In the latter part of last year, the RAFCAP (Radio Astronomy Frequency Committee in the Asia-Pacific region) was established. It, along with similar existing regional groups in America (CORF) and Europe (CRAF), will hopefully be able to preserve a sufficient portion of the necessary observing environment.

Capturing solar power in space, and transmitting it to Earth via microwave radiation, is a technology that shows significant signs of moving from a dream to reality. Our current URSI President, Hiroshi Matsumoto, and a number of others active in URSI have played important roles in making this happen. In his column in this issue on "Radio-Frequency Radiation Safety and Health," Jim Lin provides a brief history of this field. He then examines the environmental and health concerns associated with this potential method of energy production and distribution.

The Scientific Committee on Solar-Terrestrial Physics (SCOSTEP), organized under ICSU (the International Council on Science, of which URSI was one of the founding scientific unions), led to the Solar-Terrestrial Energy Program (STEP). This, in turn, led to the STEP-Results, Applications, and Modeling Phase (S-RAMP) program. The first comprehensive S-RAMP conference was held in the latter part of 2000. Yohsuke Kamide and Hiroshi Matsumoto provide a nice summary of that conference in this issue. If you are interested in learning more about these organizations and what is going on in the field of solar-terrestrial physics, visit the very interesting SCOSTEP Web pages at http://www.ngdc.noaa.gov/stp/SCOSTEP/scostep.html.

In this issue you will also find the announcement of the URSI Awards, a report on the URSI accounts, and a great deal of information on conferences of interest to radio scientists. There is also some news from ITU-R, and from the member committees. The dates of the URSI business meetings at the Maastricht General Assembly are here: incorporate these into your schedule for the General Assembly.

In Memoriam: Elva Gordon

Sadly, space normally limits our ability to mark the passing of the spouses of members of our family of radio scientists in these pages. I hope I will be forgiven for making an exception in the case of Elva Gordon, wife of URSI Honorary President Bill Gordon. Her attendance and participation in over 40 years of URSI meetings made her very special to all who knew her. The following is taken from an obituary supplied by Bill and her family at my request.

Elva Freile Gordon died at the age of 85, in the afternoon of February 22, 2002, following a stroke in her sleep about ten hours earlier. Her husband, daughter, and a chaplain were with her at the end. Elva was a sweet lady, a caring mother, a devoted grandmother, and a loving wife. Elva was born in Jersey City, New Jersey, to Bruce and Elise Freile. She grew up in Bogota, NJ, and attended Montclair State Teachers' College, earning a BA in 1938. Following her graduation, she worked as a church secretary at the Fort Washington Collegiate Church in New York City. In 1941, she married her college sweetheart, William E. Gordon. She is survived by her husband of 60 years, by her son Larry Scott Gordon and his wife Christine Gere Gordon of Centerville, MA, by her daughter Nancy Gordon Ward and her husband George B. Ward III of Austin, Texas, and by her four grandchildren, Matthew Scott Gordon, Amanda Joy Gordon, George B. Ward IV, and Elizabeth Gordon Ward. A full-time homemaker, Elva volunteered at Rice University, the Houston Museum of Natural Science, and Taping for the Blind. She was a gracious hostess to scientific dignitaries at home and abroad, and to students, faculty, and friends.

Some Final Notes

There are many scientific meetings planned for this summer, including the General Assembly. As you attend these, please keep the *Radio Science Bulletin* in mind. If you hear a paper that you think would be appropriate for the *Bulletin*, encourage the author(s) to submit it, and/or let me know. We have been getting a steady input of papers, but we need to increase the number if we're going to have the *Bulletin* become the source of broad-interest information on radio science we want it to be.

The *Review of Radio Science, 1999-2002* will go to the printer shortly after this is being written: assuming all goes well, registrants at the Maastricht General Assembly will receive this book of approximately 1,000 pages and 38 original papers in searchable form on CD-ROM (as voted by the Council in Toronto). Those who wish to will also be able to purchase a printed copy at the meeting, published by IEEE Press/John Wiley, at a substantial discount. I think you will be pleased with the book: the papers are outstanding. The topics and authors were chosen by the URSI Commissions as representing the most significant areas in radio science for the triennium. All of the contributions were extensively peer-reviewed. This is one more reason why you need to be in Maastricht!

Ross

Commission Business Meetings

During the Maastricht General Assembly, most scientific commissions will hold Business Meetings at the following dates:

- **Monday 19 August 2002 at 6 p.m.**
- **Wednesday 21 August 2002 at 6 p.m.**
- **Friday 23 August at 6 p.m.**

Exceptions are:

- Commission G & H will hold Business Meetings on Monday and Friday at 6 p.m. in the Commission G & H rooms; however on Wednesday Commissions G & H will hold a joint meeting in the Commission H room. Commission H will continue with Commission H Business meeting in the same room subsequent to this meeting, if time permits
- Commission K requests to hold its Business Meetings only on Monday 19 August and Wednesday 21August.

URSI Accounts 2001

The URSI balance for 2001 already reflects the increasing expenditures for the coming GA 2002. The most important differences with respect to the year 2000 are the following:

- income was about 128 kEuro less than 2000, mainly because of: arrears of Member Countries (»50 k, most if it paid in the mean time), late levies for the 1999-GA paid in 2000 (»42 k), reinvestments of assets in 2000 (» 28k).
- expenditures were about 34 kEuro higher than in 2000, mainly because of: preparation meetings for GA 2002 (»21 k), more scientific activities in Commissions (»10 k), higher administrative costs (»10 k, due to modest salary increases, telephone and copies paid in 2001 for 2000 and 2001), but reduced publication costs (»-5 k).
- assets shrunk by about 19 kEuro in order to balance the excess expenditures over decreased income.

Nevertheless the URSI finances are still sound and we are well prepared for the GA 2002.

Paul Lagasse, Secretary General
Kristian Schlegel, Treasurer

BALANCE SHEET: 31 DECEMBER 2001

ASSETS	US$	US$	EURO	EURO
Dollars				
Merrill Lynch WCMA	12,505.68		14,043.88	
Fortis	36,530.38		41,023.62	
Smith Barney Shearson	48.60		54.58	
		49,084.66		55,122.08
Belgian Francs				
Banque Degroof	2,351.10		2,640.28	
Fortis	40,782.36		45,798.59	
		43,133.46		48,438.87
Investments				
Demeter Sicav Shares	22,794.75		25,598.50	
Rorento Units	111,969.73		125,742.01	
Aqua Sicav	64,103.22		71,987.92	
Merrill-Lynch Short Term (405 units)	3,717.19		4,174.40	
Massachusetts Investor Fund	277,478.91		311,608.82	
	480,063.80		539,111.65	
342 Rorento units on behalf of van der Pol Fund	12,476.17		14,010.74	
		492,539.97		553,122.39
Short Term Deposito		105,039.88		117,959.79
Total Assets		689,797.97		774,643.13
Less Creditors				
IUCAF	26,935.74		30,248.84	
ISES	4,640.80		5,211.62	
		-31,576.54		-35,460.46
Balthasar van der Pol Medal Fund		-12,476.17		-14,010.74
NET TOTAL OF URSI ASSETS		**645,745.26**		**725,171.93**

The net URSI Assets are represented by:	US$	US$	EURO	EURO
Closure of Secretariat:				
Provision for Closure of Secretariat		60,000.00		67,380.00
Scientific Activities Fund:				
Scientific Activities in 2002	90,000.00		101,070.00	
Publications in 2002	60,000.00		67,380.00	
Young Scientists in 2002	50,000.00		56,150.00	
Administration Fund in 2002	80,000.00		89,840.00	
I.C.S.U. Dues in 2002	20,000.00		22,460.00	
		300,000.00		336,900.00
XXVII General Assembly 2002 Fund:				
During 2000-2001-2002		150,000.00		168,450.00
Total allocated URSI Assets		510,000.00		572,730.00
Unallocated Reserve Fund		135,745.26		152,441.93
		<u>645,745.26</u>		<u>725,171.93</u>

Statement of Income and expenditure for the year ended 31 December 2001

I. INCOME	US$	US$	EURO	EURO
Grant from ICSU Fund and US National Academy of Sciences	5,000.00		5,615.00	
Allocation from UNESCO to ISCU Grants Programme	0.00		0.00	
UNESCO Contracts	0.00		0.00	
Contributions from National Members	127,293.57		142,950.68	
Contributions from Other Members	0.00		0.00	
Special Contributions	5,226.14		5,868.95	
Contracts	0.00		0.00	
Sales of Publications, Royalties	1,780.94		2,000.00	
Sales of scientfic materials	0.00		0.00	
Bank Interest	13.05		14.65	
Other Income	3,351.50		3,763.73	
Total Income		**<u>142,665.20</u>**		**<u>160,213.01</u>**

II. EXPENDITURE

A1) Scientific Activities		57,954.09		65,082.44
General Assembly 2002	19,965.74		22,421.53	
Scientific meetings: symposia/colloqiua	32,281.02		36,251.58	
Working groups/Training courses	0.00		0.00	
Representation at scientific meetings	5,707.33		6,409.33	
Data Gather/Processing	0.00		0.00	
Research Projects	0.00		0.00	
Grants to Individuals/Organisations	0.00		0.00	
Other	0.00		0.00	
Loss covered by UNESCO Contracts	0.00		0.00	

A2) Routine Meetings		5,643.93		6,338.13
Bureau/Executive committee	5,643.93		6,338.13	
Other	0.00		0.00	
A3) Publications		17,379.72		19,517.43
B) Other Activities		9,449.72		10,612.03
Contribution to ICSU	5,887.83		6,612.03	
Contribution to other ICSU bodies	3,561.89		4,000.00	
Activities covered by UNESCO Contracts	0.00		0.00	
C) Administrative Expenses		66,135.82		74,270.53
Salaries, Related Charges	48,007.45		53,912.37	
General Office Expenses	9,085.90		10,203.47	
Office Equipment	2,240.85		2,516.47	
Audit Fees	4,864.12		5,462.41	
Bank Charges	1,937.50		2,175.81	
Currency translation difference (USD => EURO)	0.00		0.00	
Total Expenditure:		**156,563.28**		**175,820.56**

Excess of Income over Expenditure	-13,898.08	-15,607.55
Currency translation difference (USD => EURO) - investments	20,651.30	23,191.41
Currency translation difference (USD => EURO) - bank accounts	1,578.42	1,772.57
Currency translation difference (USD => EURO) - others	0.10	0.11
Accumulated Balance at 1 January 2001	668,228.37	750,420.46
	654,330.29	**734,812.91**

Rates of exchange:

January 1, 2001:	$ 1 = 43.35 BEF	1.074691 EUR
December 31, 2001:	$ 1 = 45.30 BEF	1.123000 EUR

	US$	EURO
Balthasar van der Pol Fund:		
684 Rorento Shares: market value on December 31, 2000 (Aquisition Value: USD 12.476,17)	23,023.33	25,855.20
Market Value of investments on December 31, 2000:		
DEMETER SICAV:	43,210.31	48,525.18
RORENTO UNITS (1):	437,577.92	491,400.00
AQUA-SICAV:	66,024.73	74,145.77
M-L SHORT TERM	3,175.20	3,565.75
MASSACHUSETTS INVESTOR FUND:	229,858.43	258,131.02
	779,846.59	**875,767.72**

(1) Including the 684 Rorento Shares of the van der Pol Fund

APPENDIX: Detail of Income and Expenditure

	US$	US$	EURO	EURO
I. INCOME				
Special contributions				
Young Scientist Programme	5,000.00		5,615.00	
Young Scientist Programme	226.14		253.95	
		5,226.14		5,868.95
Other Income				
Interest on Short Term Deposito	2,635.61		2,959.79	
Interest on M-L Short Term	713.97		801.79	
Interest on Massachusetts Investor Fund	1.91		2.15	
		3,351.49		3,763.73
II . EXPENDITURE				
General Assembly 2002				
General Assembly - Travel Expenses Officials	19,965.74		22,421.53	
		19,965.74		22,421.53
Symposia/Colloquia/Working Groups:				
Commission A	2,046.66		2,298.40	
Commission B	7,541.49		8,469.09	
Commission C	1,780.94		2,000.00	
Commission D	890.47		1,000.00	
Commission E	5,339.28		5,996.01	
Commission F	5,342.83		6,000.00	
Commission G	890.47		1,000.00	
Commission H	3,373.18		3,788.08	
Commission J	890.47		1,000.00	
Commission K	4,185.22		4,700.00	
		32,281.01		36,251.58
Contribution to other ICSU bodies				
IUCAF 2000 and 2001	3,561.89		4,000.00	
		3,561.89		4,000.00
Publications:				
Printing 'The Radio Science Bulletin'	8,469.71		9,511.48	
Mailing 'The Radio Science Bulletin'	8,910.02		10,005.95	
		17,379.73		19,517.43

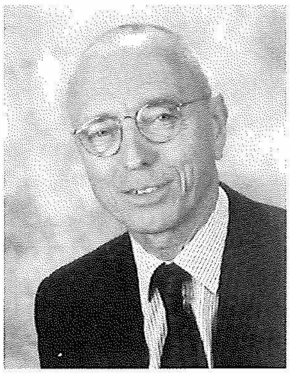
URSI AWARDS 2002

The URSI Board of Officers decided at their April 2002 meeting in Ghent to follow the recommendations of the Awards Panel and to give the 2002 Awards to the following distinguished scientists:

The Balthasar Van der Pol Gold Medal

The Balthasar Van der Pol Gold Medal will be awarded to Prof. Adrianus T. de Hoop with the citation :

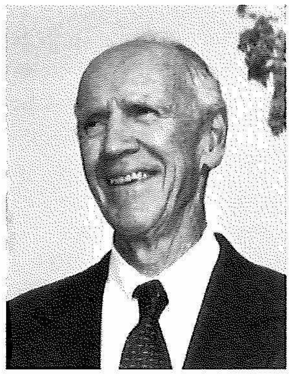
"For fundamental contributions to the theory of radiation and scattering of waves."



John Howard Dellinger Gold Medal

The John Howard Dellinger Gold Medal will be awarded to Prof. Donald L. Carpenter with the citation:

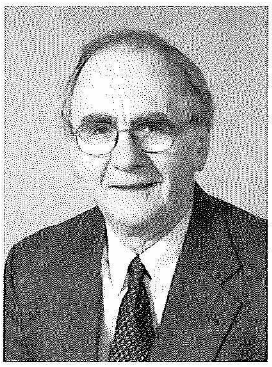
"For his discovery of the plasmapause, for pioneering studies of the plasmasphere structure and dynamics and for development and use of whistler-mode waves as diagnostic probes of the magnetosphere."



Appleton Prize

After considering the views submitted by the Awards Advisory Panel, the Board of Officers submitted a short list of candidates in order of preference, with reasons for the order, to the Royal Society.

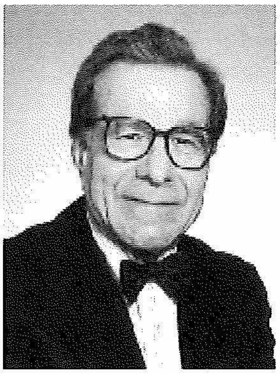
The Council of the Royal Society approved the recommendation of the URSI Board to award the 2002 Appleton Prize to Dr. Raymond A. Greenwald, with the citation :



"For conceiving, designing, developing and deploying two ground-breaking measurement techniques that have provided unparalleled spatial and temporal measurements of the ionosphere, and for inspirational international leadership."

Booker Gold Medal

The Booker Gold Medal will be awarded to Prof. Simon Haykin with the citation :

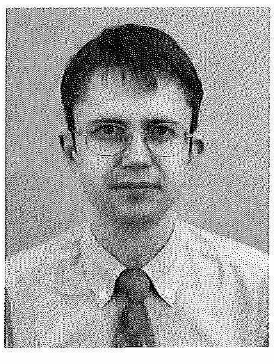


"For significant and fundamental contributions to adaptive signal processing and neural networks, and their applications to radar and digital communications, the characterizations of which are dominated by nonstationary physical phenomena."

Koga Gold Medal

The Koga Gold Medal will be awarded to Prof. Frank Olyslager, with the citation :

"In recognition of his work on theoretical and numerical electromagnetics (in particular in the field of boundary integral equations, waveguides and bianisotropic media)."



The Awards will be presented at the Opening Ceremony of the XXVII General Assembly, at the MECC in Maastricht, the Netherlands, on Sunday 18 August 2002 at 4 p.m.

News from ITU-R

The previous edition of RSB (March 2002) contained one of a series of brochures aimed at promoting membership of the ITU Radiocommunication Sector, and in particular that of ITU-R **Associates**, by publicizing the activities of the various ITU-R Study Groups. (See http://www.itu.int/ITU-R/associate-members/index.html concerning ITU-R Associates and http://www.itu.int/members/index.html on ITU membership in general). In this present edition, the brochure describing the work of Study Group 3 (Radiowave Propagation) is reproduced below.

Each brochure begins with a general preamble on the ITU and the Radiocommunication Sector, and ends with some remarks about ITU-R Associates – this being a category of membership that may well be of interest to the URSI community. However, in the interests of brevity, these parts of the brochure have not been repeated here since they were included in the March 2002 RSB article.

ITU-R Study Group 3
Radiowave Propagation

Propagation of radio waves in ionized and non-ionized media and the characteristics of radio noise, for the purpose of improving radiocommunication systems

Chairman: **D. G. COLE** (Australia)
Vice-Chairmen: **B. ARBESSER-RASTBURG** (European Space Agency)
D. V. ROGERS (Canada)

The following four Working Parties (WP) carry out studies on the Questions assigned to Study Group 3:

WP 3J Propagation fundamentals
WP 3K Terrestrial point-to-area propagation
WP 3L Ionospheric propagation
WP 3M Terrestrial point-to-point and Earth-space propagation

The principal aim of the Working Parties is to draft **Recommendations** in the ITU-R **P Series** for subsequent adoption by Study Group 3, and approval by the Member States. The Working Parties also develop **Handbooks**, which provide descriptive and tutorial material, especially useful for developing countries. A further task of the Working Parties is to provide, through Study Group 3, propagation information and advice to other ITU-R Study Groups in their preparation of the technical bases for Radiocommunication Conferences. Such information typically concerns identifying relevant propagation effects and mechanisms, and providing propagation prediction methods. The predictions are needed for the design and operation of radiocommunication systems and services, and also for the assessment of frequency sharing between them.

ITU-R Working Party 3J

Fundamental principles and mechanisms of radiowave propagation in non-ionized media

(Chairman: G. BRUSSAARD, the Netherlands)

WP 3J provides information and develops models describing the fundamental principles and mechanisms of radiowave propagation in non-ionized media. Such material is used as the basis of propagation prediction methods developed by the other Working Parties. WP 3J also addresses the topic of radio noise arising from both natural and man-made sources, and provides information to quantify the effect of noise on the performance of radio systems.

Recognizing the natural variability of the propagation medium, WP 3J prepares texts describing the statistical laws relevant to propagation behaviour and the means of expressing the temporal and spatial variability of propagation data.

Propagation over terrain and obstacles involves methods for calculating diffracted fields over the smooth and irregular Earth, and quantifying the effect of vegetation along the propagation path. Maps of ground conductivity are maintained – important for frequencies at medium frequency (MF) and below - and advice is given on the use of terrain data banks in propagation prediction procedures.

One of the principal areas of study in WP 3J concerns propagation through the neutral atmosphere, encompassing the propagation effects both in the clear-air and when precipitation is present. To this end, the WP devotes much effort to the global mapping of radiometeorological parameters used for quantifying such effects for prediction procedures. Clear-air effects include atmospheric refraction and attenuation due to atmospheric gases, these in turn requiring vertical profiles of temperature and water vapour with their spatial and temporal variation. Similarly, studies of the effects of precipitation on radiowaves, such as attenuation and depolarization, require precise global mapping of rainfall intensity, as well as models of specific attenuation of rain. WP 3J also studies the effects of cloud and fog.

Since an objective of Study Group 3 is to provide prediction procedures that are applicable world wide, it is very important that any underlying radiometeorological data are representative of the different climates of the world, and that their spatial and temporal resolution is adequate.

ITU-R Working Party 3K

Prediction methods for terrestrial point-to-area propagation paths

(Chairman: R. GROSSKOPF, Germany)

WP 3K is responsible for developing prediction methods for terrestrial point-to-area propagation paths. In the main, these are associated with terrestrial broadcasting and mobile services, short-range indoor and outdoor communication systems (e.g. Wireless Local Area Networks), and with point-to-multipoint wireless access systems.

In the VHF and UHF bands, field strength prediction takes account of the effects of terrain in the vicinity of the transmitter and receiver, and of the refractive nature of the atmosphere. Allowance is also made for location variability for land area coverage prediction with account taken of local clutter surrounding the receiver. Consideration is also given to mixed paths crossing both land and sea. A consolidated prediction procedure has been developed, suitable for broadcasting, land mobile, maritime mobile and certain fixed services (e.g. those using point-to-multipoint systems), allowing the appropriate values of antenna height and path distance to be applied. Such a prediction procedure represents a major tool for the frequency planning of broadcasting and mobile services, particularly in the range 1-3 GHz, and for coordination when frequency sharing is involved.

At higher frequencies (typically from around 1 to 100 GHz), the emphasis is on short-range systems, either indoor or outdoor, as might be used by WLAN and personal mobile communications. The WP develops Recommendations that describe the relevant propagation mechanisms such as reflection, scattering and diffraction associated with buildings, or with obstacles within buildings, all of which give rise to effects such as attenuation and multipath. The latter plays a vital part in the channel modelling of a radio link, with which an assessment of performance quality may be obtained. For outdoor situations, models are developed describing different types of environment (urban to rural) and expressions are developed for quantifying the resulting path loss.

With the growing interest in delivery of broadband services through local access networks, WP 3K studies the propagation effects associated with millimetric radio systems (e.g. operating around 20-50 GHz) used for point-to-multipoint distribution. Prediction of area coverage has to address the effects of buildings, their spatial distribution, attenuation and scattering from vegetation, and attenuation by rain. Methods to quantify the relevant propagation effects such as attenuation, and distortion due to multipath, are a key area of study in WP 3K.

ITU-R Working Party 3L

Radiowave propagation in and through the ionosphere

Chairman: J. WANG (USA)

WP 3L is responsible for all aspects of radiowave propagation in and through the ionosphere. Recommendations are maintained describing, in mathematical terms, a reference model of ionospheric characteristics and expressions for maximum usable frequencies associated with the various ionospheric layers. Short-term and long-term ionospheric forecasting, with guidance on the use of ionospheric indices, is also addressed.

As regards propagation prediction methods, Recommendations are maintained containing prediction procedures for ionospheric propagation in bands from ELF to VHF. Those for computing sky-wave propagation at LF, MF and HF play an important role in frequency planning, both for quantifying the wanted signal as well as for interference assessment. At higher frequencies, there are also methods for computing the field strength due to meteor-burst propagation as well as propagation via sporadic E. Current studies of MF and HF ionospheric propagation prediction concentrate on the effects of the ionosphere on digitally modulated transmissions, and try to extend the concept of performance reliability, already developed for analogue systems, to its digital counterpart.

With the increasing use of satellite systems, particularly those using low-Earth orbits, the effects of the ionosphere on slant propagation paths at VHF and UHF frequencies demands considerable attention. For example, the additional time delay associated with propagation through the ionosphere is of major concern for navigation satellite systems; likewise, trans-ionospheric scintillation can be a significant factor on the link budget of systems operating well above 1 GHz. WP 3L is improving methods to quantify such effects, taking into account their temporal and geographical variability.

In order to improve the accuracy of ionospheric propagation prediction, emphasis has been placed over many years on the collection and maintenance of measurement data with which predictions can be compared. In this respect, a method has been specified for acquiring HF field strength measurements from a world wide network of dedicated transmitters. Guidance is also given on making meaningful comparisons between predictions and measurements.

ITU-R Working Party 3M

Radiowave propagation over point-to-point terrestrial paths and Earth-space paths

(Chairman: M. P. M. Hall, United Kingdom)

WP 3M addresses radiowave propagation over point-to-point terrestrial paths and Earth-space paths, both for wanted and unwanted signals. For terrestrial paths, prediction methods are developed for both line-of sight and over-the-horizon links, taking into account the possible mechanisms that can give rise to fading and distortion of the wanted signal. The resulting predictions, generally expressed in terms of a statistical distribution of propagation loss or outage, provide vital information for terrestrial link planning in the fixed service (FS).

Similarly, propagation impairments on slant paths from satellites are treated by a series of Recommendations that contain prediction procedures which quantify the relevant effects and, in turn, provide an assessment of overall propagation loss, fading behaviour or signal depolarization. Recommendations are available that apply to the fixed-satellite service (FSS), the mobile-satellite service (MSS) and the broadcasting-satellite services (BSS).

In order to take proper account of the relevant propagation effects in the various prediction procedures - e.g. refractivity effects of the clear atmosphere and attenuation due to atmospheric gases and to precipitation - use is made of the many Recommendations developed by WP 3J, which provide basic radiometeorological data from which such effects can be quantified. Similarly, for predictions associated with the terrestrial fixed service, the diffraction model developed by WP 3J plays a major role, together with information on the terrain height distribution along the path. For those prediction procedures associated with satellite services, additional factors particular to the environment in the vicinity of the receiver may have to be considered, e.g. shadowing and blockage by buildings, absorption by building material. Use is also made of trans-ionospheric propagation information developed in WP 3L. In the case of mobile-satellite services, attention must be paid to the movement of the receiver, as well as to changes in elevation angle when the satellite is in low-Earth orbit.

Preliminary studies are also under way on propagation prediction for optical communications on Earth-space paths, supported by information from WP 3J on the relevant atmospheric effects at optical frequencies.

In order to develop and test its prediction procedures, WP 3M relies on databanks of measurement data to develop and test its prediction procedures. Such databanks exist for terrestrial and Earth-space paths, and are based on long-term measurements submitted by the membership. Considerable importance is paid to quality assessment of the data to verify their accuracy and statistical validity.

A further major responsibility of WP 3M is the prediction of signals likely to cause interference. These signals, typically propagating via short-term mechanisms such as ducting and rain scatter, can give rise to unacceptably high interference levels when frequencies are shared. Prediction procedures are developed and maintained whereby such signal levels may be quantified between two points on the Earth's surface for a desired percentage of time, or between a space station and a point on the Earth's surface. Again, the predictions rely on basic radiometeorological data to quantify the refractivity of the atmosphere, or the level of rainfall intensity, associated with the propagation of these high level, short-term signals. A related and equally important aspect of the studies is the provision of a method for determining the coordination area around an earth station – a physically defined area used by administrations in their planning and deployment of terrestrial and earth stations (in the FS and FSS respectively) when sharing the same frequency band. WP 3M is responsible for developing the propagation method upon which the currently accepted international method for determining the earth station coordination area is based.

Kevin A. Hughes

The Review of Radio Science 1999 - 2002

The fourth triennial *Review of Radio Science, 1999-2002* will be available at the XXVIIth General Assembly of URSI, to be held in Maastricht, The Netherlands, 17-24 August 2002. For the first time, at the direction of the URSI Council, this approximately 1000-page book will be given to all paid registrants on CD-ROM. As a result, the contents will be fully searchable. Also for the first time, the book is being published by the IEEE Press/John Wiley. Those wishing to purchase printed copies will be able to do so at a discount at the General Assembly. The following is the final Table of Contents for the book.

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Assessment of the Health Effects of EMF Exposure

M.H. Repacholi

Abstract

The World Health Organization (WHO), through its International EMF Project, has conducted a number of reviews of possible health effects from exposure to fields from various parts of the electromagnetic spectrum. These fields can be grouped into radio frequencies (RF), intermediate frequencies (IF), and the static and extremely low frequencies (ELF). In addition, there have been substantial reviews published by other organizations, in many of which WHO representatives have participated. This paper describes WHO's International EMF Project activities and their results so far, briefly reviews the biological effects from EMF exposure, identifies gaps in knowledge needing further research, and overviews WHO's current published position on these issues.

The main conclusion from the WHO reviews is that EMF exposures below the limits recommended in the guidelines by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) do not appear to have any known consequence on health. However, there are still some key gaps in knowledge, needing further research before better health risk assessments can be made. These research needs are being promoted to funding agencies by WHO. Because of remaining uncertainties in the science database, there has been some pressure to introduce precautionary measures until gaps in knowledge are filled. If precautionary measures are introduced to reduce EMF levels, it is recommended that they are made voluntary, and that health-based exposure limits be mandated to protect public health.

1. Introduction

The World Health Organization (WHO) takes seriously the concerns raised by reports about possible health effects from exposure to electromagnetic fields (EMF). Cancer, changes in behavior, memory loss, and many other diseases have been suggested as resulting from exposure to EMF. Everyone in the world is now exposed to a complex mix of EMF frequencies in the range 0-300 GHz. EMF has become one of the most pervasive environmental influences, and exposure levels at many frequencies are increasing significantly as the technological revolution continues unabated, and new applications using different parts of the spectrum are found.

Electromagnetic field sources to which people may be exposed are predominantly in three frequency ranges:

- The static (0 Hz) and extremely low frequency range (ELF, > 0 to < 300 Hz) incorporates the 50 and 60 Hz frequencies of the electric-power supply and of electric and magnetic fields generated by electricity power lines and electric/electronic appliances. Sources of static magnetic fields include magnetic resonance imaging (MRI) and industrial use of direct currents for electrolysis;
- The intermediate-frequency range (IF, 300 Hz to < 10MHz) frequencies are used in computer monitors, industrial processes, and security systems;
- The radio-frequency range (RF, microwaves, 10 MHz-300 GHz) includes radars, radio and television broadcasts, and telecommunications.

Most research has been devoted to possible biological effects from exposure to ELF or RF fields. The IF range has received little attention, despite the rapid development of appliances such as induction-heating devices, anti-theft and remote-detection systems.

This review gives a brief description of WHO's International EMF Project, with an update on activities and results; summarizes research on biological and health effects in the three frequency ranges; and identifies gaps in knowledge that need further research before better health-risk assessments can be made. In addition, WHO has published the results of reviews and conclusions as WHO Fact Sheets in multiple languages, and they are available on the EMF Project Web site at http://www.who.int/emt/.

2. International EMF Project

WHO established the International EMF Project to provide a forum for a coordinated international response to EMF issues, and to assess health and environmental effects of exposure to static and time-varying electric and magnetic fields in the frequency range 0-300 GHz. The Project commenced at WHO in 1996, and is scheduled for completion in about 2005. It has been designed to follow a logical progression of activities, to produce a series of outputs that allow improved health-risk assessments to be

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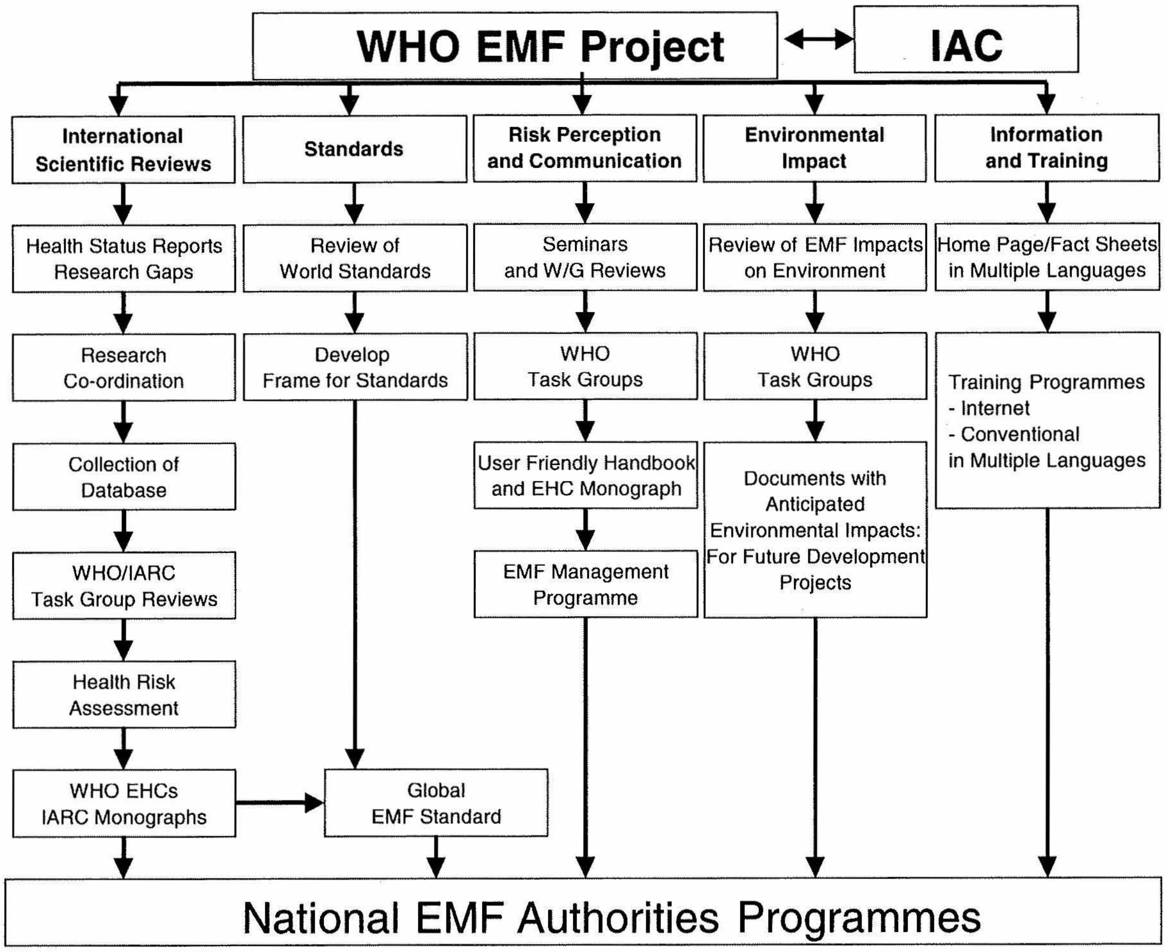

Figure 1. A schematic outline of the activities and outputs of the International EMF Project.

made, and to identify any environmental impacts of EMF exposure. The ultimate objectives of the Project are to provide sound advice to national authorities on how best to manage EMF issues, and to complete health-risk assessments that will lead to the development of an international consensus on exposure guidelines. An EMF Project overview is given in Figure 1.

2.1 Definitions

To conduct reviews and assess health consequences from EMF exposure, it is necessary to have working definitions of biological effects and health hazards. Explicit distinctions are made between the concepts of interaction, biological effect, and health hazard, consistent with the criteria used by international bodies when making health assessments [1]. Biological effects occur when fields interact to produce physiological responses that may or may not be perceived by people. Deciding whether biological or physiological changes have health consequences depends, in part, upon whether they are reversible, whether they are within the range for which the body has effective compensation mechanisms, or whether they are likely, taking into account the variability of response among individuals, to lead to unfavorable changes in health.

WHO defines health as the state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity. Biological effects are defined as any measurable change in a biological system, though not all of them will be hazardous. Some may be innocuously within the normal range of biological variation and physiological compensation, and others may be beneficial under certain conditions. The health implications of others may be simply indeterminate. In this case, uncertainty adds to the lack of acceptability of scientific results. A health hazard is generally defined to result from a biological effect outside the normal range of physiological compensation or adverse to a person's well-being.

2.2 Scientific Reviews

WHO, through its International EMF Project, has recently conducted a series of in-depth international reviews of the scientific literature on the biological and health effects of exposure to radio frequency (RF), intermediate frequencies, and static and extremely low frequency (ELF) fields. These reviews were conducted mainly with the purpose of identifying;

- health effects that can be substantiated from the literature, and

- biological effects that are suggestive of possible health effects, but require further research to determine if exposure to EMF at the low levels of exposure normally encountered in the living and working environment has any impact on health.

The results of these reviews have been published [2-4]. The proceedings of all papers presented at the scientific-review conferences have been published jointly by WHO and ICNIRP, and are available from ICNIRP (http://www.icnirp.de). Having completed the initial international scientific reviews, WHO is now urging EMF funding agencies worldwide to give priority to research related to possible health effects of EMF that will allow WHO to make better health-risk assessments.

2.3 Health-Risk Assessments

Both WHO and the International Agency for Research on Cancer (IARC) have already established a timetable for assessing health effects of EMF fields. In June, 2001, the IARC formally evaluated the evidence for carcinogenesis from exposure to static and extremely low frequency (ELF) fields. The review concluded that there was sufficient evidence from the childhood leukemia studies to classify ELF magnetic fields as a "possible human carcinogen." IARC will publish the results of this meeting in the IARC Monograph Series in 2002. A WHO fact sheet describing this result and implications was published in October, 2001 [5].

The International EMF Project will use the IARC conclusions on carcinogenesis and incorporate them into a full health-risk assessment of exposure to static and ELF fields in 2002-3. The results and conclusions will be published in WHO's Environmental Health Criteria series. Sufficient results should be available for IARC to conduct a similar evaluation of evidence for carcinogenicity of RF fields in 2004. WHO would then complete an overall health-risk assessment of exposure to RF fields in 2004-5.

2.4 Standards Harmonization

In November, 1998, WHO commenced a process of harmonization of electromagnetic fields (EMF) standards worldwide. Over 45 countries and eight international organizations are involved in the International EMF Project. Thus, the Project provides a unique opportunity to bring countries together in a logical process to better define any health risks associated with EMF exposure, and to encourage the development of harmonized exposure limits and other control measures that provide the same level of health protection to all people. Globalization of trade and the rapid introduction of mobile telecommunications worldwide have focused attention on the large differences existing in standards limiting exposure to EMF. Differences in the EMF exposure-limit values in standards in some Eastern European and Western countries are, in some cases, over a factor of 100. This has raised concerns about their safety, and has led to public anxiety about increasing EMF exposures from the introduction of new technologies.

The purpose of this activity is work towards, and to hopefully achieve, international agreement on a framework for developing guidelines on protection of the public and workers from exposure to EMF. EMF is defined as electromagnetic fields in the frequency range 0 to 300 GHz. It will take some years before this activity is complete, but it is hoped that the process will be finalized before the formal assessment of EMF health-risk assessments by WHO and IARC. Thus, the next generation of standards would be able to incorporate this health-risk assessment information within the same harmonized standards framework.

2.5 EMF Risk Perception, Communication and Management

One of the EMF issues of most concern is why people perceive risks differently from scientists involved in risk assessments, and why there seems to be a breakdown in communication among the public and scientists and government. In addition, EMF exposure seems to raise peoples' concerns to a level that is incompatible with the known magnitude of other environmental hazards.

To address these concerns, international seminars were held in Vienna, in 1997, and in Ottawa, in 1998, to discuss risk perception and management of EMF fields. The seminars were followed by working-group meetings, to compile a draft report on this topic. The proceedings of the Vienna seminar were published by ICNIRP (see http://www.icnirp.de), and the proceedings of the Ottawa meeting were published by WHO in 1999 (see http://www.who.int/emf). From these reviews, there will be publications by WHO in the form of a scientific monograph and a user-friendly *Handbook*. These publications are intended to:

- Supply governmental and non-governmental authorities, as well as individuals, with a reliable source of information about this topic;
- Foster a better understanding of EMF issues, how they can be better communicated, and how fruitful resolution of disagreements can be achieved;
- Provide an easily readable overview of the characteristics and underlying assumptions of peoples' perceptions of EMF risk, differences among scientific, governmental, and popular views, and why these occur;
- Provide practical information for agencies and organizations to examine their current approaches to EMF, and to design better and more effective information and risk-management programs.

2.6 Environmental Impacts

As technology has progressed, levels of EMF in our environment have steadily increased over the past 50-100 years. At specific frequencies, EMF emissions from manmade sources now exceed those from natural fields by many orders of magnitude, and are detectable everywhere in the world. Significant increases in environmental EMF levels have resulted from major development projects, such as high-voltage transmission lines, undersea power cables, radars, telecommunication and broadcast transmitters, and transportation systems. Research has been focused on determining if EMF exposure of humans has any deleterious health consequence. By comparison, influences of these fields on plants, animals, birds, and other living organisms have been less rigorously examined. Assessments of environmental impacts of EMF fields is important to:

- Ensure the preservation of balances in natural terrestrial and marine ecosystems, since these directly impact on human life;
- Preserve food supplies by ensuring there are no adverse impacts to fisheries, agricultural animals, and plants.

An international seminar, organized by WHO and ICNIRP, and supported by the German Federal Office of Radiation Protection, was held in Ismaning, Germany, in October, 1999. It provided a summary of scientific knowledge about any consequences to the environment from manmade sources of EMF in the frequency range 0-300 GHz. Overviews of current knowledge in key areas were presented by a panel of recognized specialists. Working groups met to prepare conclusions and recommendations. The proceedings of all presentations have been published, and are available from ICNIRP (see http://www.icnirp.de). The results of the working-group meetings have been used to prepare a scientific paper for publication in a scientific journal [6].

It is not anticipated that further meetings will be organized on this topic. The main purpose of this activity was to provide information that specifically addressed environmental impacts of EMF fields. It is anticipated that the reports of the meeting will be useful for both governmental and non-governmental institutions when conducting environmental impact assessments, and will help address public concern that EMF could be adversely affecting our environment.

3. ELF Fields

Most public exposure to ELF fields comes from electrical appliances, household wiring, and AC transmission and distribution lines. In addition to the WHO review [3], other recent reviews on the health effects of static and ELF electric and magnetic fields have been conducted by IARC [7], the Health Council of the Netherlands [8], and by an expert Advisory Group of the National Radiological Protection Board in the United Kingdom [9]. All of these reviews are in basic agreement with each other, and are summarized below.

3.1 Interaction Mechanisms

A well-known mechanism of interaction of ELF fields with biological tissues is the induction of time-varying electric currents and fields. At sufficiently high levels, these can produce direct stimulation of excitable tissues, such as nerve and muscle cells. At the cellular level, the interaction induces voltages across the membranes of cells sufficient to stimulate nerves to conduct, or muscles to contract. This mechanism accounts for the ability of humans and animals to perceive electric currents in their bodies and to experience electric shocks. Other mechanisms have been proposed, but there is little evidence to support them.

3.2 Electric Fields

External ELF electric fields induce time-varying electric charges on the surface of the body. The magnitude and distribution of the charges depend on the body shape, and its location and orientation relative to the field and ground plane. In addition, electric fields, electrical polarization changes, and currents are induced inside the body, as a result of time-variation of this surface-charge density. Charges fixed on internal molecules polarize and depolarize as the field changes. Since time-variation in the ELF range is slow compared to the ability of charges to move, the fields and currents generated inside the body from this source are very small. The induced current-density distribution depends on the electrical properties of the tissue, and varies inversely with the body cross-section. Typically, the strength of the internal electric fields is less than about 10^{-6} of the external field.

3.3 Magnetic Fields

The induced current density in the body is proportional to the rate of change of the magnetic-flux density. For applied sinusoidal fields, the induced fields and currents are linearly dependent on frequency. The magnitude of the currents induced by pulsed magnetic fields will depend on the rise and fall times of the pulse. The highest current densities are induced in peripheral tissues, since these have the largest inductive-loop radius in the body. However, tissue inhomogeneity and orientation of the body to the field will affect the current path. In general, the electric field induced in peripheral tissues by a horizontal magnetic field is approximately 1.5 times that induced by a vertical magnetic field of similar magnitude. Currents circulating from head to foot due to a horizontal magnetic field will be high in the neck, because its small cross section concentrates the flow.

For a human with a torso radius of 0.15 m and tissue conductivity of 0.2 S/m, a 50 Hz magnetic field parallel to the long axis of the body will induce a current in the tissue periphery of about 5 A/m^2 per tesla. Since current density is proportional to body radius, current-density values can be used to scale between animal and human exposure. Typical induced currents and fields for 1 μT, 60 Hz uniform magnetic-field exposure of mice, rats, and humans are in the ranges of 0.1-0.4, 0.3-1.3, and 1-20 $\mu A/m^2$, respectively [3].

4. ELF Biological Effects

4.1 Laboratory Studies

The AGNIR review [9] concluded that there is no consistent evidence that exposure to ELF fields experienced in our living environment causes direct damage to biological molecules, including DNA. Since it seems unlikely that ELF fields could initiate cancer, a large number of investigations have been conducted to determine if ELF exposure can influence cancer promotion or co-promotion. Results from animal studies conducted so far suggest that ELF fields do not promote cancer.

Above about 0.1 mT, a variety of studies have demonstrated effects *in vitro* on ornithine decarboxylase (ODC) activity. Not all replication attempts have succeeded, however. Many other biological effects have been reported above about 1 mT [10]. How magnetic-field exposure produces such effects is unknown. For most effects, such as those reported on genotoxicity, intracellular calcium concentrations, or general patterns of gene expression, convincing and reproducible results have not been observed. None of the *in vitro* effects are necessarily indicative of an adverse health effect. Without knowledge of the mechanisms involved, effects observed at high field strengths cannot be extrapolated to lower fields, since the mechanisms may be different.

While there is no convincing evidence that ELF fields cause cancer in animals, only a limited number of studies have been conducted to test this hypothesis. Some recent studies suggest a positive relationship between breast cancer in animals treated with carcinogens and ELF magnetic-field exposure at approximately 0.02-0.1 mT. The importance of these findings needs to be investigated further [3]. Currently available data do not provide convincing evidence of adverse effects on reproduction or development in mammals from exposure to power-frequency fields. There is evidence of behavioral and neurobehavioral responses in animals, but only following exposure to strong ELF electric fields.

Neuroendocrine changes are associated with exposure to ELF magnetic fields, but these alterations have not been shown to cause adverse effects in animals. Some studies suggest magnetic fields of strengths between 0.01 and 5.2 mT might inhibit night-time pineal and blood melatonin concentrations in experimental animals. However, such effects have not been demonstrated in humans.

5. Human Laboratory Studies

5.1 Perception

Exposure to ELF electric fields can result in field perception, as a result of alternating electric charge induced on the surface causing body hair to vibrate. Most people can perceive electric fields greater than 20 kV/m, and few people perceive field strengths below 5 kV/m. In two well-controlled studies, humans were unable to perceive magnetic fields at levels up to 1.5 mT [3].

During exposure to ELF magnetic fields above 3-5 mT, volunteers experienced faint visual flickering sensations or magnetophosphenes. The threshold current density in the retina for induction of magnetophosphenes is about 10 mA/m^2 at 20 Hz, well above typical endogenous current densities in electrically excitable tissues. Higher thresholds have been observed for both lower and higher frequencies [3].

5.2 Cardiovascular System

Several reports indicate that ELF fields influence the cardiovascular system. Exposure of human volunteers to combined 60 Hz electric and magnetic fields (9 kV/m, 0.02 mT) resulted in small changes in cardiac function. Resting heart rates were found to be slightly but significantly reduced (about 3-5 beats/minute) during or immediately after exposure. This response did not occur with exposure to stronger (12 kV/m, 0.03 mT) or weaker (6 kV/m, 0.01 mT) fields, and was reduced if the subject was mentally alert [10]. In these double-blind studies, subjects were unable to detect the presence of the fields. While continuous exposure to combined electric and magnetic fields at 9 kV/m, 0.02 mT, slows the heart, intermittent exposure can result in both slowing and increasing heart rate. None of the effects on heartbeat exceeded the normal range. No obvious acute or long-term cardiovascular-related hazards have been demonstrated at levels below current exposure standards for ELF or radio-frequency fields.

5.3 Hormone and Immune-System Effects

No changes in blood chemistry, blood-cell count, blood gases, lactate concentration, skin temperature, or circulating hormones have been observed. Field-related suppression of the hormone melatonin has been proposed as a mechanism for the relationship between exposure to magnetic fields and increased cancer risk [3]. However, well-controlled laboratory studies report mostly negative results, although some laboratory studies have reported positive results. No published reports have examined possible differential effects in women, possible influence of longer exposure, or of altering field polarization.

Classification	Examples of Agents
Carcinogenic to humans (usually based on strong evidence of carcinogenicity in humans)	Asbestos Mustard gas Tobacco (smoked and smokeless) Gamma radiation
Probably carcinogenic to humans (usually based on strong evidence of carcinogenicity in animals)	Diesel engine exhaust Sun lamps UV radiation Formaldehyde
Possibly carcinogenic to humans (usually based on evidence in humans which is considered credible, but for which other explanations could not be ruled out)	Coffee Styrene Gasoline engine exhaust Welding fumes ELF magnetic fields

Table 1: Examples of physical and chemical agents classified for carcinogenicity by IARC

5.4 Epidemiological Studies

ELF fields are known to interact with tissues by inducing electric fields and currents in them. This is the only established mechanism of action of these fields. However, the electric currents induced by ELF fields commonly found in our environment are normally much lower than the strongest electric currents naturally occurring in the body, such as those that control the beating of the heart. Since 1979, when epidemiological studies first raised a concern about exposures to power-line-frequency magnetic fields and childhood leukemia, a large number of studies have been conducted to determine if measured ELF exposure can influence cancer development, especially in children.

A Working Group, formed by the National Institute of Environmental Health Sciences[10] to evaluate the health effects from exposure to ELF, concluded that ELF magnetic fields are a *possible human carcinogen*. The evidence in support of this decision resulted from studies on childhood leukemia in residential environments, and on chronic lymphocytic leukemia (CLL) in adults in occupational settings. This conclusion is essentially in agreement with recent reviews in the UK [9], the Netherlands [8], and the IARC classification [7], discussed below.

Pooled analyses [11, 12] of the epidemiological studies on exposure to ELF magnetic fields suggest that residence in homes near external power lines is associated with an approximate 1.5-2.0 fold relative risk of childhood leukemia. These studies suggest that, in a population exposed to average magnetic fields in excess of 0.3 to 0.4 μT, twice as many children might develop leukemia compared to a population with lower exposures. In spite of the large numbers in the database, some uncertainty remains as to whether magnetic-field exposure or some other factor(s) might have accounted for the increased leukemia incidence. These uncertainties occur for a number of reasons. Childhood leukemia is a rare disease, with four out of 100,000 children between the age of 0 to 14 diagnosed every year. Also, average magnetic-field exposures above 0.3 or 0.4 μT in residences are rare. Less than 1% of populations using 240-volt power supplies are exposed to these levels, although this may be higher in countries using 120-volt supplies.

These pooled analyses were influential for a working group of the International Agency for Research on Cancer (IARC), concluding that ELF magnetic fields were a "possible human carcinogen" for childhood leukemia. "Possibly carcinogenic to humans" is a classification used to denote an agent for which there is limited evidence of carcinogenicity in humans, and less than sufficient evidence for carcinogenicity in experimental animals.

This classification is the weakest of three categories ("is carcinogenic to humans," "probably carcinogenic to humans," and "possibly carcinogenic to humans") used by IARC to classify potential carcinogens based on published scientific evidence. Some examples of well-known agents that have been classified by IARC are given in Table 1. A full listing of the evaluations of carcinogenicity to humans of all physical, chemical, and biological agents classified by IARC is available from their Web page at http://www.iarc.fr. WHO has published a fact sheet [5] that explains this classification, and advises on options that can be taken to address the concerns raised by such a classification.

Occupational studies have generally used job titles – sometimes in combination with workplace ELF field measurements – to determine if any association exists between exposure to these fields and cancer. Elevated risks of various cancers have been reported, especially leukemia, nervous-system tumors, and breast cancer; but the lack of uniformity of the results has been a major concern. Any excess cancer risk among electrical workers, compared to other occupations, is small, and difficult to detect using epidemiological methods. Studies so far have been complicated by the lack of adequate exposure assessment in the workplace, and possible confounding factors.

The basic problem with all epidemiological studies so far has been the lack of any concept of dose, or an exposure metric established from laboratory studies. Metrics used have generally been cumulative exposure or time-weighted average field strength. Very little information has been obtained about exposure from appliances, ground currents, or devices that may be associated with transient fields. Brief exposures to high-amplitude magnetic-field transients, or to high-frequency harmonics, have not been assessed in published studies. Personal dosimeters do not exist that can capture this information.

6. ELF Research Needs

Independent replication of some key studies is a high priority. When effects are robust, replication should be straightforward, and can be used as a basis for extending observations. It is important to characterize the dose-response relationship (field strength, threshold, and exposure duration) of any effect, particularly at environmentally relevant field strengths. Where possible, *in vivo* studies should consider exposures that include intermittence, transients, and duration as important variables. In addition, it would be valuable to consider the interactions of ELF fields with other agents, such as ionizing radiation and chemicals. These interactions should test the hypothesis that ELF fields may act as a co-promoter for cancer, but other end points suggested by the *in vitro* literature should also be examined. Wherever possible, exposures should be relevant to those experienced by humans in occupational and residential settings. Some cancer-related studies using various animal models are currently under way. Research gaps identified by WHO are as follows:

- Confirmation and extension of animal studies reporting increased tumor incidence when magnetic fields are applied in combination with chemical carcinogens. These experiments should focus on dose-response relationships and the relationship between different exposure conditions.
- Confirmation and extension of studies suggesting that magnetic-field exposure influences mammary-cancer development. Possible changes in relevant hormonal factors in magnetic-field-exposed animals and controls should be investigated to examine potential mechanisms.
- Neurophysiology/neurobehavioral studies using models of neurodegenerative diseases are indicated because of

recent reports of possible ELF-field influence on human neurodegenerative diseases, such as Alzheimer disease.

- While most studies of ELF field effects on various endpoints in reproduction and development have been negative, new studies should provide information on long-term neurobehavioral consequences following *in utero* exposure to magnetic fields. These studies should address whether ELF fields can produce effects on early brain development, as measured in functional behavior in adult animals.

6.1 Epidemiology Research Needs

The most important prerequisite for future epidemiological studies is a clearer understanding of what metric should be used to characterize ELF field exposure. This may come from laboratory work or from additional hypothesis-generating epidemiological studies, each of which has advantages and disadvantages in cost, time, and precision. Project designs for new epidemiological research should, within the limits of what is possible, increase the role of measured past and present exposures. Dependence on surrogates, such as wire codes and job classifications, should decrease, particularly if data do not exist that establish how well the surrogates select for historical exposure. The *a priori* estimates of the power of future studies must be strong enough to predict useful information, given the outcomes of past research.

Because many – but not all – studies show a small but significant excess in childhood leukemia associated with residence in high-wire-code homes in the US (the only country where this surrogate has been used), a concerted effort is needed to explain this association. While efforts have been made to define the relationship between wire codes and average magnetic-field exposure or socio-economic confounding factors, little evidence is available about the relationship between wire codes and high-amplitude transient fields or high-frequency harmonics. Future studies should include these and ground currents in the exposure assessments. Another aspect to be seriously pursued in future studies is the inclusion of non-occupational exposure.

With the above caveats, needed future epidemiological studies should:

- Address the relationship between exposure and cancer incidence that properly assesses both residential and occupational exposure over long periods, including transient magnetic-field exposure and high-frequency harmonics.
- Determine if correlates of wire codes – such as traffic density, age of home, and socio-demographic characteristics of home occupants – can explain the statistical relationship between wire codes and childhood leukemia.
- Study the relationship between breast cancer and field exposure, including evaluation of both average field levels and of transients and high-frequency components, and taking into account both occupational and non-occupational exposures.
- Investigate the relationship between neurodegenerative disorders and field exposure, including an evaluation of the role of average field levels, transients, and high-frequency components. Both occupational and non-occupational exposures should be considered.
- Study the relationship between heart disease endpoints and exposure to ELF fields, including evaluation of the role of transient and high-frequency components, and taking into account both occupational and non-occupational exposures.

6.2 Volunteer Studies

Further studies are needed, especially using transient and high-frequency components typical of environmental ELF fields, to determine:

- Whether any component of the human melatonin hormone system is susceptible to ELF field exposure and, if so, the likely health consequence of this susceptibility.
- Whether sleep disruption, changes in neurotransmitter metabolism, and learning and memory are associated with ELF field exposure.
- The relationship between field exposure and slowing and variability in heart rate.
- Whether electrophysiological indices of central nervous system activity and function are affected by ELF fields.

6.3 Subjective Effects

Given the limited evidence, but widespread concern, about subjective effects, more research is needed to determine whether these health effects can be substantiated, and can be related to EMF exposure. The current laboratory results should be extended, and their relevance clarified.

7. Intermediate Frequencies

Compared to the extremely low frequency (ELF) and radio-frequency (RF) ranges, few biological-effects studies have been conducted, and few reviews have been published, that focus on health risks from IF sources. International EMF-exposure guidelines [13] at IFs have been established by extrapolating limits from the ELF and RF frequency ranges, based on principles of the coupling of external fields with the body, and assumptions about the frequency dependence of bioeffects. Because applications of EMF in this frequency range are increasing rapidly, it is important to properly evaluate the significance of any effects on human health.

A wide range of equipment produces electric or magnetic fields in the IF range. Common sources of IF fields include monitors and video-display units (3-30 kHz), AM radio (30 kHz-3 MHz), industrial induction-heating devices (0.3-3 MHz), and anti-theft and remote-detection systems. In most cases, the exposures to humans from these devices are within recommended limits, although the guidelines may be exceeded in some cases. Workers in a few occupational groups (operators of heat sealers and induction heaters, some military personnel, technicians working near high-powered broadcast equipment) are undoubtedly exposed to considerably higher levels of IF fields than the general population.

7.1 Mechanisms of Interaction

Understanding the mechanisms of interaction between EMF and biological systems is important for several reasons. First, determining the thresholds for hazard at IFs currently requires extrapolation of biological data from lower- and higher-frequency ranges. For this, an understanding of the mechanisms for effects is important. More generally, hypotheses about mechanisms of interaction can help clarify biological phenomena and guide further experimentation.

Several mechanisms, both thermal (above about 100 kHz) and non-thermal (below about 100 kHz), by which electromagnetic (primarily, electric) fields can interact with biological systems, are well established. Each mechanism is characterized by a strength of interaction and a response time [4]. The first determines the threshold for producing observable effects in the presence of random thermal agitation (noise). The second determines the frequency response of the effect, which is typically characterized by a cutoff frequency (above which the threshold increases with frequency). In addition, EMFs can heat tissue, resulting in a variety of thermal effects. The limiting hazard will arise from the adverse effect (thermal or non-thermal) that has the lowest threshold under given exposure conditions.

8. IF Biological and Health Effects

Most biological-effects studies in the IF range have employed field levels far above exposure guidelines, and above realistic exposure levels for humans. However, in some cases, the exposure levels have been below recommended limits. Virtually none of the effects described below have any apparent explanation in terms of accepted biophysical mechanisms of interaction. The results and conclusions included here are from a recent WHO meeting [4].

Most studies have used field levels above international guidelines for human exposure, or otherwise have unclear relevance to normal exposure situations. As with other EMF ranges, few reported effects of IF fields have been subjected to independent confirmation, and, in some cases, investigators have suggested the presence of confounding effects that may have led to previously reported effects of IF. Most epidemiological studies on human exposure to IFs concern possible reproductive effects, and were motivated by health concerns from exposure to fields emitted by VDUs [video display units]. Other studies have been reported on workers occupationally exposed to fields in the IF range. However, because of the weak associations in these studies, the use of multiple comparisons in the data analysis, and other uncertainties, they provide no strong evidence for health hazards.

The working group formed during the WHO meeting on the IF range, held in Maastricht in June, 1999, felt that the health implications of these findings are difficult to assess. The general consensus was that current scientific evidence does not show the presence of health hazards from IFs at exposures below recommended guidelines. However, the biological data are sparse, particularly related to effects of low-level exposure. A few epidemiology studies have suggested links between IF exposure and health effects, but they are compromised by technical problems, and cannot be reliably interpreted. Even for established hazards, there is a need to better determine thresholds, particularly for fields with complex waveforms, or pulsed fields. Any epidemiological studies at IFs should be preceded by pilot studies demonstrating their feasibility.

9. Radio-Frequency Fields

Common sources of RF fields include RF heat sealers, medical diathermy (3-30 MHz), FM radio (30-300 MHz), mobile telephones, television broadcasts, microwave ovens, medical diathermy (0.3-3 GHz), radar, satellite links, microwave communications (3-30 GHz) and the sun (3-300 GHz).

The hazards of exposure to high levels of RF fields, which result in tissue heating, are basically understood, although there are still a number of unresolved issues. Thermal hazards are associated with acute exposures, and are thought to be characterized by thresholds, below which they are not present. However, many studies have suggested that RF exposure at lower-than-thermal levels may have biological effects, but they have either not been consistently replicated, or else their significance for human health cannot be adequately assessed using information currently available. Scientific research into possible health effects has been unable to keep pace with the rapid advances in the applications of RF fields in our working and living environment. This delay has led to widespread concerns among the general public and workforce that there are unresolved health issues that need to be addressed as a matter of urgency.

Although many reports in the scientific literature claim effects in biological systems exposed to low levels of RF, the mechanisms for these reported effects are unknown, and their relevance for human health is uncertain.. In this respect, one of the major challenges is to better understand and more clearly establish the effects reported at low RF levels.

9.1 Mechanisms of Interaction

RF fields induce torques on molecules, which can result in displacement of ions from unperturbed positions, vibrations in bound charges (both electrons and ions), and rotation and reorientation of dipolar molecules, such as water. These mechanisms, which can be described by classical electrodynamic theory, are not capable of producing observable effects from exposure to low-level RF fields, because they are overwhelmed by random thermal agitation. Moreover, the response time of the system must be fast enough to allow it to respond within the time period of the interaction. Both considerations imply that there should be a threshold (below which no observable response occurs) and a cutoff frequency (above which no response is observed). These thresholds would be expected to be present even in more-refined models, if they correctly take into account thermal noise and the kinetics of the system.

Exposure to EMF at frequencies above about 100 kHz can lead to significant absorption of energy and to temperature increases. In general, exposure to a uniform (plane-wave) electromagnetic field results in a highly non-uniform deposition and distribution of energy within the body, which must be assessed by dosimetric measurement and calculation. For absorption of energy by the human body, electromagnetic fields can be divided into four ranges:

- frequencies from about 100 kHz to less than about 20 MHz, where absorption in the trunk decreases rapidly with decreasing frequency, and significant absorption may occur in the neck and legs;
- frequencies in the range from about 20 MHz to 300 MHz, at which relatively high absorption can occur in the whole body, and to even higher values if partial-body (e.g., head) resonances are considered;
- frequencies in the range from about 300 MHz to several GHz, at which significant local, non-uniform absorption occurs;
- frequencies above about 10 GHz, at which energy absorption occurs primarily at the body surface.

10. RF Biological Effects

The information below is taken from reviews by WHO [2], the International Commission on Non-Ionizing Radiation [13], and an Independent Expert Group on Mobile Phones [14] in the UK.

10.1 In Vitro

Reports from *in vitro* research indicate that low-level RF fields may alter membrane structural and functional properties, which trigger cellular responses. It has been hypothesized that the cell membrane may be susceptible to low-level RF fields, especially when these fields are amplitude-modulated at ELF frequencies. At high frequencies, however, low-level RF fields do not induce appreciable membrane potentials. They can penetrate the cell membrane and possibly influence cytoplasmic structure and function. These RF field-induced alterations, if they occur, could be anticipated to cause a wide variety of physiological changes in living cells that are only poorly understood at the present time.

A lack of effect of RF exposure on mutation frequency has been reported in a number of test samples, including yeast and mouse lymphoid cells. No effect of RF-field exposure on chromosome-aberration frequency in human cells has been confirmed [2].

10.2 Animal Studies

In contrast to the evidence given above, several rodent studies indicate that RF fields may directly affect DNA. These papers report quantitative data, subject to sources of inter-trial variation and experimental error, such as incomplete DNA digestion or unusually high levels of background DNA fragmentation. These experiments need to be replicated before the results can be used in any health-risk assessment, especially given the weight of evidence that RF fields are not genotoxic. Further, in animal studies, most well-conducted investigations report a lack of clastogenic effect in the somatic or germ cells of exposed animals [13]. Other investigations that require further attention relate to possible synergistic action of RF exposures with chemical or physical mutagens or carcinogens.

Most cancer studies of animals have sought evidence of changes in spontaneous or natural cancer rates, enhancement by known carcinogens, or alterations in growth of implanted tumors [13]. However, they have provided only equivocal evidence for changes in tumor incidence. Chronic RF-field exposure of mice at 2-8 W/kg resulted in an SAR-dependent increase in the progression or development of spontaneous mammary or chemically induced skin tumors. In a further study, exposure at 4-5 W/kg, followed by application of a sub-carcinogenic dose of a chemical carcinogen to the skin, a procedure repeated daily, eventually resulted in a three-fold increase in skin tumors. However, at these high exposures, temperature-mediated effects cannot be excluded.

Studies in which cancer cells were injected into animals have reported a lack of effect of exposure to CW and pulsed RF fields on tumor progression. Progression of melanoma in mice was unaffected by daily exposure to pulsed or CW RF fields following subcutaneous implantation, and progression of brain tumors in rats was not affected by CW or pulsed RF fields following the injection of tumor cells into the brain.

Moderately lymphoma-prone Eμ-*Pim1* oncogene-transgenic mice were exposed or sham-exposed to radio-frequency fields for 1 h/day for up to 18 months, using pulse modulations similar to that used for digital mobile telephones. Exposure was associated with a statistically significant, 2.4-fold increase in the risk of developing lymphoma [15]. This long-term study needs replication, and extension to other exposure levels and animal models, before it can be used for health-risk assessments. Further research is also needed to determine the significance of effects in this transgenic model for human health risk.

Although weak evidence exists, it fails to support an effect of RF exposure on mutagenesis or cancer initiation. There is scant evidence for a co-carcinogenic effect, or an effect on tumor promotion or progression. However, only a few studies have been published, and these are sufficiently indicative of an effect on carcinogenesis to merit further investigation.

10.3 Effects on Other Systems

While many studies have been conducted at high levels of RF exposure, few relevant studies have used low levels. Some of the more important studies are described below.

The blood-brain barrier (BBB) is a specialized neurovascular complex that functions as a differential filter, permitting selective passage of material from the blood into the brain. It maintains the physiological environment of the brain within certain limits that are essential for life. Although extensive previous research has been unable to reliably identify permeability changes at low levels of RF exposure, in recent studies increased BBB permeability was reported for RF exposures at SARs as low as 0.016 W/kg. These studies need replication and extension to allow a better determination of any possible health consequence.

Exposure to very low levels of amplitude-modulated RF fields were reported to alter electrical activity in the brains of cats and rabbits. These experiments need replication and extension.

Early signs of neurotoxicity are often behavioral rather than anatomical. Current Western standards are based on behavioral changes occurring in response to temperature elevations in excess of one degree Celcius. However, few studies have been conducted at low RF levels, and there is a need to do these [14].

10.4 Pulsed Radiation

Exposure to low-level pulsed and CW RF fields has been reported to affect brain neurochemistry in a manner consistent with responses to stress. Effects on behavior and drug interaction have been obtained with the same exposure parameters. Replication studies are needed to establish and provide further information on these effects.

Exposure to very intense pulsed RF fields suppresses the startle response and evokes body movements in conscious mice [13]. The mechanism for these effects is not well established, and is clearly associated with heating at higher absorbed energies.

People having normal hearing perceive pulse-modulated RF fields with carrier frequencies between about 200 MHz and 6.5 GHz: the so-called *microwave hearing* effect. The sound has been variously described as a buzzing, clicking, hissing, or popping sound, depending on modulation characteristics. Prolonged or repeated exposure may be stressful [2].

The retina, iris, and corneal endothelium of the primate eye were reported to be susceptible to low-level RF fields, particularly when pulsed. Various degenerative changes in light sensitive cells in the retina were reported at specific energies per pulse (10-μs pulses at 100 pps) as low as 2.6 mJ/kg, after the application of a drug used in glaucoma treatment. However, these results could not be replicated for CW fields [2].

11. Epidemiological and Human Volunteer Studies

11.1 Cancer

By far the greatest public concern has been that exposure to low-level RF fields may cause cancer. Of the epidemiological studies addressing possible links between RF exposure and excess risk of cancer, some positive findings were reported for leukemia and brain tumors. Review groups that evaluated possible links between RF exposure and excess risk of cancer have concluded that there is no consistent evidence of a carcinogenic hazard. In some studies, there are significant difficulties in assessing disease incidence with respect to RF exposure, and with potential confounding factors such as ELF and chemical exposure. Overall, the epidemiological studies suffer from inadequate assessment of exposure and confounding, and poor methodology [14].

Overall, the results are inconclusive, and do not support the hypothesis that exposure to RF fields causes or influences cancer. However, epidemiological studies in some 14 countries, coordinated by IARC, are underway to determine if there is any relationship between mobile phone use and head or neck cancers. These studies should provide substantial new information on RF exposure and its relationship to cancer causation. Further studies are under way to evaluate potential carcinogenic effects of chronic exposure to low-level RF fields, and more are needed.

11.2 Other Outcomes

Other health outcomes investigated following RF exposure include headaches, general malaise, short-term memory loss, nausea, changes in EEG and other central nervous system functions, and sleep disturbances. There have also been anecdotal reports from several countries of subjective disorders, such as headaches, associated with the use of mobile telephones. Whether exposure to RF fields at very low levels can cause such subjective effects has not been substantiated from current evidence, but further research is indicated.

Individuals have claimed to be hypersensitive to electromagnetic fields. The most common symptoms are headaches, insomnia, tingling and rashes of the skin, difficulty in concentrating, and dizziness. Given the limited evidence and widespread concerns that the above effects have provoked, more research is needed to determine if these health effects can be substantiated.

Adverse maternal health outcomes, particularly spontaneous abortions and hematological or chromosome changes, have been reported to occur in certain populations exposed to RF fields. Some of these changes have also been reported in users of video-display units. Taken overall, the studies in this area have not substantiated these effects [2, 13, 14].

12. RF Field Research Needs

Since the EMF Research Agenda was first published by WHO in 1996, many national and international agencies have funded research that contributes substantially towards the studies needed to make better health-risk assessments. Most of the *in vivo* and *in vitro* studies have now been completed, or are under way.

12.1 Human Laboratory Studies

By far the most-important deficiency in the RF research under way is in the area of effects on human volunteers. There is still a basic need to perform studies on human volunteers, under laboratory conditions, to determine basic physiological responses to pulsed, non-thermal levels of RF, similar to those emitted by mobile telephones. It is anticipated that following the recommendations of the Stewart report [14], a further $10 million will be devoted to this research, with emphasis on human laboratory studies. Using established batteries of tests or study designs, there is a need to investigate:

- Psychological effects related to the use of mobile phones as well as measurable changes in blood pressure, brain, and cognitive function (including memory or learning), any other effects likely to effect the CNS, reaction times, auditory-evoked potentials, EEG, ECG, EKG, and others;
- Biological effects on human brain function to determine if it is affected by different RF pulsing regimens (test to Hyland-Frölich hypothesis);

- RF effects on children to determine if they are more sensitive than are adults;
- People who claim to show a greater sensitivity to RF fields; hypersensitivity reactions, sleep disturbance, other subjective effects.

12.2 Animal Studies

While a number of studies are in progress under contracts from the 5th Framework program of the European Commission, and a major study has been announced under the US National Toxicology Program, there is still a need for the following:

- Address long-term memory and behavioral studies in animals, since this cannot be done effectively in humans;
- Follow-up study on cancer promotion using DMBA.

12.3 In Vitro *Studies*

As a lower priority, there is a need to conduct:

- *In vitro* investigations of ODC and cell-signaling molecules. The ODC results need to be resolved, as well as the ongoing debate about calcium efflux.
- Hippocampal slice preparation studies, showing transient changes in evoked and spontaneous activity.
- More complete studies of the possibility that pulsed RF fields can initiate gene expression.

13. Conclusions and Recommendations

All reviews conducted so far have indicated that exposures below the limits recommended in the ICNIRP EMF guidelines [13], covering the full frequency range from 0-300 GHz, do not produce any know adverse health effects. While there is more research needed in areas already identified before better health-risk assessments can be made, it is likely that if any adverse effect on health is found from EMF exposure, it will be minor.

WHO is now in the process of making a complete assessment of health risks and risk estimation for the whole EMF range. The results of this will not be available for a few years, but it is expected that they will impact on the management of EMF. The degree of public concern and remaining uncertainties in the science base (mainly, whether long-term, low-level exposures will impact on health), have meant that there has been a significant move towards determining whether precautionary measures should be invoked, until science is able to address remaining issues. WHO has provided information on this [16, 17] for member states.

Recommendations have been issued by WHO through a series of fact sheets [2, 18, 19]. They deal with EMF exposure limitation and precautionary measures that might be adopted, and can be summarized as follows:

- Adopt mandatory health-based EMF exposure limits (such as [13]) to protect public health;
- Adopt, as needed, voluntary precautionary measures that reduce unnecessary EMF expose to address public concern.

Examples of possible precautionary measures that could be adopted have been published in [17].

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The Need for a United Asia-Pacific Radio Astronomy Front

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Abstract

Radio signals from the cosmos can be incredibly faint: Typical spectral power-flux densities as low as -320 dB $Wm^{-2}Hz^{-1}$ are being detected, and even fainter signals are being sought. Because of this, the signals are potentially very susceptible to interference from transmitting services. There are increasing demands for radio spectrum by new or evolving transmitting services, with an increasing threat to radio astronomy, unless the spectral bands used for radio-astronomical observations can be protected.

The usage of the radio spectrum is regulated on an international scale by the International Telecommunication Union (ITU), a specialized agency of the United Nations organization, by means of the International Radio Regulations. These Regulations are revised at a World Radiocommunication Conference (WRC), held about every three years. Improved protection for radio astronomy can be obtained only at these meetings, and it is extremely important that worldwide representation of radio astronomers, with united proposals, be present. Administrations have already found that the formation of regional groups, such as CEPT (Conference Européenne des Administration des Postes et des Télécommunications), CITEL (Comisión Interamericana de Telecomunicaciones), etc., in which common proposals have been established in advance of WRCs, has been very effective in protecting regional interests. In our region, administrations have formed the Asia-Pacific Telecommunity (APT), and it played a major role at WRC-2000. For radio astronomy, regional groups have been set up in America (CORF: Committee on Radio Frequencies) and Europe (CRAF: Committee on Radio Astronomy Frequencies), and these promote radio astronomy's views in CITEL and CEPT, respectively. To enable effective negotiation of protection for radio astronomy within the APT, a similar group, representing radio astronomers in the Asia-Pacific region – the Radio Astronomy Frequency Committee in the Asia-Pacific region (RAFCAP) – has been established.

1. Radio Astronomy as a Radiocommunication Service

Radio astronomy and the radio astronomy service as a radiocommunication service are defined in Article 1, Nos. 14, 55, and 92 of the Radio Regulations of the ITU as being astronomy based on the reception of cosmic radiowaves. The aggregate of these cosmic emissions constitute the cosmic background noise of communications engineering. Being a passive service, radio astronomy service does not involve the transmission of radio waves in its allocated bands, and, therefore, the use of these bands cannot cause interference to any other service. On the other hand, the cosmic signals received are extremely weak (typical spectral power flux densities as low as -320 dB $Wm^{-2}Hz^{-1}$ are routinely observed), and are therefore very susceptible to interference by transmissions of other services. At present, radio astronomy utilizes the electromagnetic spectrum at frequencies from below 1 MHz to about 1000 GHz, well beyond the 275 GHz currently allocated in the Radio Regulations. The entire radio spectrum is of scientific interest to the radio astronomy service.

Radio astronomy began in 1932, when Karl Jansky discovered the existence of radio waves of extra-terrestrial origin, and it is now established as an important branch of observational astronomy. For the solar system, it has increased our knowledge of the Sun (e.g., the physical processes responsible for the emissions of plasmas), and also of the planets and the interplanetary space. On a larger scale, multi-frequency studies of cosmic sources of radio emission have provided information about interstellar gas clouds and star formation within them, interstellar magnetic fields, the structure and the evolution of galaxies, and the Universe as a whole. Spectral-line emissions of atoms and molecules at naturally occurring frequencies have provided information about the composition, the physical characteristics, and the motions of interstellar gas clouds. Much of the information obtained by radio astronomy is unique, and cannot be obtained at other than radio wavelengths.

In contributing to our knowledge of astronomy, the radio astronomy service has also contributed to other areas. It has provided information on the atmospheric absorption of radio waves, which is of interest to telecommunications. It has also contributed to communication technology. Its pioneering research has led to continuing development of low-noise amplifier techniques, extending to progressively higher frequencies and wider bandwidths, and the production of receiver systems with ever increasing sensitivity. In

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some cases, sensitivities approach the theoretical limits. In practice, system temperatures lower than 20 K have been reached. Significant contributions have been made to the design of feed systems and large steerable antennas. The technique of very-long-baseline interferometry (VLBI) is also important for geodetic measurements, and for the accurate tracking of spacecraft. The development of very-large-scale integration (VLSI) chips to process the data collected by radio-astronomy arrays has applications in other areas of electronics and physics. The sophisticated image-processing techniques developed by radio astronomers have a direct application in areas such as medicine and mining.

In the study of cosmic radio sources, radio astronomers measure all the properties of electromagnetic radiation. These are the intensity, frequency, polarization, direction (the position in the sky), and temporal variations of these parameters. Cosmic radio emissions have low power-flux-density levels at the Earth. Most show the characteristics of random noise. Exceptions are (a) the pulsed emissions at extremely regular rates from pulsars, (b) interplanetary and ionospheric scintillations of small-diameter radio sources, (c) irregular bursts from some stars (including the Sun), (d) variations on the scale of months for some radio sources, and (e) variations associated with the planet Jupiter. The best times for observation of radio sources are generally dictated by natural phenomena (the position of the source in the sky and the rotation of the Earth). Unlike the situation in active (transmitting) services, the radio astronomer cannot change the character of the signal to be received: the emitted power cannot be increased, nor the signal coded, in order to increase detectability.

2. Vulnerability of Radio Astronomy Observations to Interference

The radiation measured in radio astronomy has, in almost all cases, a Gaussian probability distribution in amplitude. Generally, it cannot be distinguished from thermal-noise radiation of the Earth or its atmosphere, or from noise generated in a receiver. In radio-astronomy observations, the signal-to-noise ratios in the radio-frequency (RF) and intermediate-frequency (IF) parts of the receiver are typically in the range of -20 dB to -60 dB, i.e. the power contributed by the source under study is a factor of 10^{-2} to 10^{-6} lower than the unwanted noise power from the atmosphere, the ground, and the receiver circuits. In most communication systems, the corresponding signal-to-noise ratio is of the order of unity or greater. Because radio-astronomy signals are so weak in comparison to those of other services, radio-astronomy observations are highly vulnerable to radio interference. To exacerbate the problem, cosmic signals generally have no characteristic modulation that would help to distinguish them from noise, or from many forms of interfering signals.

The reason that observations with very low signal-to-noise ratios can give useful measurements is that when the total noise power in the receiver IF stages is measured using a detector, and the output of the detector is averaged for many seconds (or, in some cases, many hours), the statistical fluctuations in the measured values are greatly reduced. It is commonly possible to detect fractional changes in the total noise level that are of the order of 10^{-6} or lower. An example of the high sensitivity of radio-astronomy observations is the detection of the angular structure in the cosmic background radiation by the Cosmic Background Explorer (COBE) satellite, in 1992. Fluctuations of the order of 10^{-5} of the 2.7 K background temperature were measured, which are 70 dB below the system noise temperature, 200-400 K, of the receivers on the satellite. The high sensitivity of such observations is obtained at the expense of information on short-time variations of any signal characteristics, which are lost in the averaging that is essential to reducing the noise fluctuations.

3. International and Regional Organizations to Treat Frequency-Allocation Problems

3.1 The Radiocommunication Sector and World Radiocommunication Conferences of the ITU

This document is concerned principally with aspects of radio astronomy that are relevant to frequency coordination, that is, the usage of the radio spectrum in a manner regulated to avoid interference by mutual agreement between the radio services. On an international scale, the regulation of spectrum usage is organized through the International Telecommunication Union (ITU), which is a specialized agency of the United Nations.

The Radiocommunication Sector, which is a part of the ITU, was created on 1 March 1993 to implement the new ITU structure. The Radiocommunication Sector includes World and Regional Radiocommunication Conferences, Radiocommunication Assemblies, the Radio Regulations Board, Radiocommunication Study Groups, the Radiocommunication Advisory Group, and the Radiocommunication Bureau, headed by the elected Director. The Radiocommunication Assembly and the Radiocommunication Bureau replaced the International Consultative Committee on Radio (CCIR) and its Secretariat, which performed similar functions.

The ITU Radio Regulations, which are the basis of the planned usage of the spectrum, are the result of World Radiocommunication Conferences (WRCs), which are held at intervals of a few years. At such conferences, the aim is to introduce new requirements for spectrum usage in a form that is, as far as possible, mutually acceptable to the representatives of participating countries. The results of each WRC take the form of a treaty, to which the participating administrations are signatories. As in most areas of international law, the enforcement of the regulations is difficult, and depends largely upon the good will of the participants.

Radiocommunication Study Groups are set up by a Radiocommunication Assembly. They study questions and prepare draft recommendations on the technical, operational, and regulatory/procedural aspects of radio communications. These ITU-R Study Groups address such issues as preferred frequency bands for the various services, threshold levels of unacceptable interference, sharing between services, desired limits on emissions, etc. These groups are further organized into Working Parties and Task Groups, which deal with specific aspects of Study Group work. As of 2001, the ITU-R Study Groups were as follows:

Study Group 1	Spectrum management
Study Group 3	Radio wave propagation
Study Group 4	Fixed-satellite service
Study Group 6	Broadcasting service (terrestrial and satellite)
Study Group 7	Science services
Study Group 8	Mobile, radiodetermination, amateur and related satellite services
Study Group 9	Fixed service
SC	Special Committee on Regulatory/ Procedural Matters
CCV	Coordination Committee for Vocabulary
CPM	Conference Preparatory Meeting

Radio astronomy falls within ITU-R Study Group 7, Science Services, which also includes space sciences, time signals, and frequency standards. In the work of the Study Group, the search for extraterrestrial intelligence (SETI), radar astronomy as practiced from the surface of the Earth, and space-based radio astronomy are usually included with radio astronomy.

International meetings of the Study Groups and Working Parties occur at approximately two-year intervals, and are attended by delegations from many countries. The Task Groups are usually set up for a limited period of time to carry out specific tasks, and meet at intervals according to their needs. Appropriate Questions are assigned to the Study Groups, which provide responses, generally in the form of ITU-R Recommendations. The ITU-R Recommendations provide a body of technical, operational, and regulatory/procedural information that has been agreed upon by the participating administrations. This information is used to provide technical inputs to WRCs, and many of the results of the work of the Study Groups are thereby incorporated into the Radio Regulations. Aside from this, the ITU-R Recommendations and Reports are, in themselves, generally regarded as authoritative guidelines for spectrum users. This is particularly true of the ITU-R Recommendations, which are widely followed, and are revised and published on a four-year cycle by the ITU. Since 1990, the Reports are no longer carried forward in current ITU publications. Most of the important material on radio astronomy in Study Group 7 Reports has been revised.

3.2 The Radio Regulations and Frequency Allocations

International frequency allocations are carried out at WRCs, attended by representatives of more than 180 administrations from all over the world. For the purpose of allocation, the world is divided into three regions: Region 1 includes Europe, Africa and northern Asia; Region 2 includes North America and South America; and Region 3 includes southern Asia and Australasia. For any particular frequency band, the allocations may be different in different regions. Bands are often shared between two or more services. Generally speaking, the allocations are primary or secondary. A service with a secondary allocation is not permitted to cause interference to a service with a primary allocation in the same band. The frequency allocations are contained in Article 8 of the Radio Regulations. Most are shown in a table of allocations; however, additional allocations are contained in numbered footnotes to the table.

Within individual countries, spectral allocation matters are handled by government agencies. The agencies vary greatly from one administration to another. In many countries, the administration of the radio spectrum is part of the work of a larger agency, which may also include areas such as postal and telephone services, transportation, commerce, etc. Such agencies play major roles in the preparation of national positions that are advocated at WRCs. Administrations participating in the WRC treaties retain sovereign rights over the spectrum within their national boundaries, and can deviate from the international regulations to the extent that this does not cause harmful interference within the territories of other administrations. In the setting up of the Radio Regulations, many administrations have claimed exceptions in certain bands, in order to cover particular national requirements.

3.3 Frequency Allocation Problems for Radio Astronomy

Several features of radio astronomy are different from those of the majority of services that use the radio spectrum. Radio astronomy is a passive service, concerned only with the reception of data. A few other services, such as Earth exploration by satellite, also use passive sensing.

Radio astronomy signals are very weak, with power flux densities typically 40 to 100 dB below those utilized by most other services. The highly sensitive receiving systems that are required in radio astronomy are very vulnerable to interference. This vulnerability is exacerbated by the nature of the cosmic signals. Most signals have the form of random noise, with no characteristic modulation that would allow them to be distinguished from other signals. The sharing of frequency bands with active services is difficult. It is usually not possible to share when there is a direct line-of-sight between a radio-astronomy antenna and a transmitter in the same band. A further problem is emission produced in a radio-astronomy band by active services operating in other bands. This is becoming more common as the use of broadband digital-modulation and spread-spectrum techniques continues to increase. Because of this potential threat to radio astronomy, mere preservation of allocations is not sufficient to guarantee interference-free radio-astronomical observations.

Radio astronomers cannot always choose their frequencies arbitrarily. Many of the cosmic signals that they study take the form of spectral lines, covering a limited frequency range. These lines are generated at characteristic frequencies associated with transitions between quantized energy states of atoms or molecules. Thus, allocations for observation of these lines must be made at specific frequencies. Allocations for many of the more important lines were obtained in the past, when the radio spectrum was less heavily used by other services. Additional allocations will be required, but will be difficult to obtain. Important new lines continue to be detected, and many of them are not within allocated bands. For spectral lines in distant galaxies, an observed frequency that normally falls within a radio-astronomy band may be Doppler shifted outside the band, because of the large motions of the galaxies relative to the Earth. Therefore, practically all parts of the radio spectrum are of potential scientific interest. However, because of allocations to active services, observations at many frequencies are severely restricted, or not even possible. In some cases, it may be possible to minimize interference by choosing appropriate locations for telescopes, or times for observation.

Because radio astronomers have great difficulty in sharing frequencies with active services, and because they cannot choose their frequencies arbitrarily, radio astronomy is not easily accommodated within the system of allocations and regulations. Nevertheless, the series of bands allocated to radio astronomy is vital to the existence of the service, and has enabled a stream of important scientific discoveries to be made over the past three decades.

3.4 Radio Astronomy in the ITU

Radio astronomy was first officially recognized as a radio-communication service at the WARC (World Administrative Radio Conference) of 1959. At that time, under the auspices of the International Council of Scientific Unions (ICSU), three scientific unions set up a commission, the Inter-Union Commission for the Allocation of Frequencies for Radio Astronomy and Space Science (IUCAF), to represent scientific usage of the radio spectrum. The three founding unions are the International Astronomical Union (IAU), the International Union of Radio Science (URSI), and the Committee on Space Research (COSPAR); each contributes to the membership of IUCAF. IUCAF participates in WRCs as a recognized International Organization, but has no voting rights. Radio astronomers work through their national agencies or IUCAF to get their concerns considered by the Radiocommunication Sector, or included on the agenda of a WRC. In addition to IUCAF, National and Regional committees – for example, the US Committee on Radio Frequencies (CORF) and the European Committee on Radio Astronomy Frequencies (CRAF) – facilitate a united participation by radio astronomers. Figure 1 illustrates some of the interrelationships between agencies involved in frequency-coordination processes for radio astronomy. In Figure 1, the following abbreviations are use (in alphabetical order):

CORF	Committee on Radio Frequencies
COSPAR	Committee on Space Research
CRAF	Committee on Radio Astronomy Frequencies
IAU	International Astronomical Union
ICSU	International Council of Scientific Unions
ITU	International Telecommunication Union
IUCAF	Inter-Union Commission for the Allocation of Frequencies for Radio Astronomy and Space Science
RA	Radiocommunication Assembly
SG 7	Study Group 7
URSI	International Union of Radio Science
WRC	World Radiocommunication Conference

In Article 1, Section 1 of the Radio Regulations, radio astronomy is defined as astronomy based on the reception of radio waves of cosmic origin. In the table of frequency allocations, frequency bands that offer the greatest protection to radio astronomy are those for which the radio astronomy service has a primary allocation shared only with other passive (non-transmitting) services. Next in degree of protection are the bands for which radio astronomy has a primary allocation, but shares this status with one or more active (transmitting) services. Less protection is afforded where bands are allocated to radio astronomy on a secondary basis.

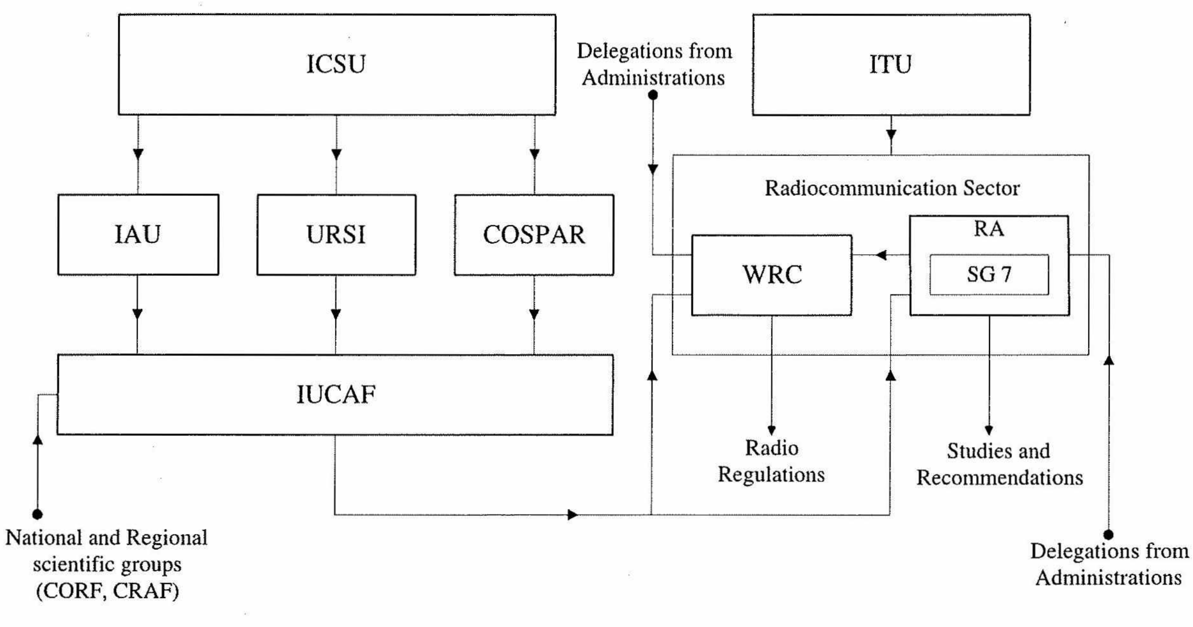

Figure 1. Interrelationships between international agencies involved in frequency coordination for the radio astronomy service.

For many frequency bands, the protection is by footnote, rather than by direct table listing. The footnotes are of several types. For an exclusive band allocated only to passive services, the footnote points out that all emissions are prohibited in the band. Other footnotes are used when radio astronomy has an allocation in only part of the band appearing in the table. A different form of footnote is used for bands or parts of bands that are not allocated to radio astronomy, but which are nevertheless used for astrophysically important observations. It urges administrations to take all practicable steps to protect radio astronomy when making frequency assignments to other services. Although such footnotes provide no legal protection, they have often proven valuable to radio astronomy when coordination with other services is required.

4. The Success of CRAF and CORF

Administrations have already found that the formation of regional groups, such as CEPT, CITEL, etc., in which common proposals have been established in advance of WRCs, has been very effective in protecting regional interests. For radio astronomy, regional groups have been set up in America (CORF) and Europe (CRAF), and these promote radio astronomy views in CITEL and CEPT, respectively.

CRAF has regular meetings at least twice per year, and contributes to submitting European common views and proposals for relevant Study Group meetings and WRCs. An excellent example is the success of extending frequency allocations for radio astronomy above 71 GHz, which was made in WRC-2000. Radio astronomy could not extend its frequency allocations after 1979. Therefore, radio astronomers of CRAF, CORF, and some astronomers from the Asia-Pacific region collaborated to negotiate with other services within their regions, and succeeded in submitting very similar proposals for WRC-2000. Thus, discussion among participating administrations during WRC-2000 ran very smoothly, and radio astronomy was able to get new frequency allocations of more than 80 GHz in total, in the frequency region between 71 and 275 GHz. CRAF and CORF prepared radio-astronomy proposals to CEPT and CITEL, respectively, and played major roles in getting them adopted as the regional common proposals. Submission of such common proposals is quite effective at helping radio astronomers realize what they need, when they take the decision-making procedures within ITU into account.

Although the frequency problems are regulated under national laws, radio waves propagate regardless of the national borders. Therefore, it is quite necessary to have common views between neighboring countries on any frequency allocation/regulation issues. The role of CRAF and CORF hence will be more important in the future.

5. The Need to establish a Radio Astronomy Frequency Committee in the Asia-Pacific Region (RAFCAP)

In the Asia-Pacific region, administrations have formed the Asia-Pacific Telecommunity (APT), and it played a major role at WRC-2000. However, there has not been any regional radio-astronomer's group to collaborate on the frequency-allocation problems. The APT's regional meetings for preparation of WRCs are called APGs. As was seen in Europe and in America, it would be quite effective for a radio-astronomer's group to participate the APG meetings, to solve the frequency-allocation problems of radio astronomy. So far, only a small number of active radio astronomers, from Australia, India, Japan, and the Republic of Korea, have worked as their national delegates. When they refer to the success of CRAF and CORF, it is clear that they need a more coordinated radio-astronomy group, to effectively reflect their opinions into the APG common proposals.

In our region, several countries have radio-astronomical facilities: Australia, China (Peoples Republic of), India, Japan, and Korea (Republic of). Although Taiwan has no radio-astronomical facilities at present, radio astronomers in Taiwan have been participating in the SMA (SubMillimeter Array) project. In 1999, it was discussed to establish a group to collaborate on the frequency issues in the 4th East Asia Meeting of Astronomy, held in Kunming, Yunnang, China. The participants agreed to support the establishment of such a group.

The Asia-Pacific countries have very different situations in their infrastructures on radio communication. For developing countries, it is an economic decision to introduce mobile phones, rather than wired phones, in establishing communication networks. Therefore, the radio-observational environment will be polluted more and more, unless radio astronomers act to protect themselves.

6. Establishment of the RAFCAP

During the last AP-RASC (Asia-Pacific Radio Science Conference), held from 31 July to 4 August, 2001, in Tokyo, there was a business meeting (3 August) to discuss the need to establish a radio-astronomers group to handle the frequency issues in the Asia-Pacific region. I made a presentation explaining the need to set up the group. Dr. Ananthakrishnan (India), Dr. Chung (Korea, Republic of), and Dr. Tzioumis (Australia) reported on national activities to protect radio astronomy in each country. After discussion among participants in the meeting, the RAFCAP (Radio Astronomy Frequency Committee in the Asia-Pacific region) was launched successfully!

The initial members of the RAFCAP are as follows:

Chairperson Masatoshi Ohishi (NAO, Japan)
Secretary Tasso Tzioumis (ATNF, Australia)

S. Ananthakrishnan and T. L. Venkatasubramani (GMRT, TIFR, India)
H. S. Chung (Korea Astr. Obs., Korea, Republic of)
X. Hong (Shanghai Obs., P. R. China)
M. Inoue (NRO, NAO, Japan)
J. Lim (IAA, Taipei)
U. Shankar (RRI, India)
S. Wu (National Astr. Obs., P. R. China)

7. Conclusion

The RAFCAP (Radio Astronomy Frequency Committee in the Asia-Pacific region) has been successfully established, and the appendix provides a proposed draft charter of the committee, which was created by referring to that of CRAF (square-bracketed parts are tentative, in the manner of the ITU). Although the RAFCAP needs financial support in the near future, it is necessary to actually begin work as soon as possible, and to show how the committee can be so effective in protecting radio astronomy in the Asia-Pacific region. It is planned to have the first plenary meeting during the 3rd APG meeting, which is scheduled to be held in June, 2002, in Bangkok.

8. Bibliography

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2. *Recommendations for the Radio Astronomy*, Geneva, ITU, 1997.
3. *CRAF Handbook for Radio Astronomy*, CRAF, 1997.

9. Appendix

Proposed Draft Charter of the Radio Astronomy Frequency Committee in the Asia-Pacific Region (RAFCAP)

CHARTER

With Terms of Reference

1. RAFCAP Status and Mission

RAFCAP acts as the scientific expert committee on frequency issues for the Asia-Pacific radio astronomy and related sciences.

The mission of RAFCAP is :

(a) to keep the frequency bands used for radio astronomical observations free from interference.

(b) to argue the scientific needs of radio astronomy for continued access to and availability of the radio spectrum for radio astronomy within the Asia-Pacific region.

(c) to support related science communities in their needs of interference-free radio frequency bands for passive use.

2. RAFCAP Terms of Reference

RAFCAP will:

. provide scientific advice for the co-ordination of a common Asia-Pacific policy on frequency protection for radio astronomy, and related sciences;

. promote understanding on the issue of passive frequency use for scientific observations;

. provide a discussion forum on interference issues in passive frequency use, and increase public awareness of these fields at the Asia-Pacific level and the international level.

In the pursuit of these tasks, RAFCAP will interact with the relevant major bodies and supranational entities at the Asia-Pacific and international level.

RAFCAP Committee Members are required to maintain links with their national observatories involved in radio astronomy and with their national radiocommunications administrations.

3. RAFCAP Committee Membership and Structure

Committee Members are drawn from reputed experts active in all fields of radio astronomy and related sciences on the basis of scientific or technical expertise and recognition within the community, so as to ensure the authority and credibility of the Committee. A credible representation of the Asia-Pacific radio astronomy observatories and a geographical balance of the Committee's membership needs to be ensured.

The Committee Members are appointed for a three-year term, normally renewable, after appropriate consultation with RAFCAP and with the respective national bodies.

The Chairperson of RAFCAP is appointed in response to his/her nomination by the RAFCAP Committee. The search for candidate(s) for its chairperson is undertaken by a Search Panel set up by the Committee. The term of the RAFCAP chair is three years with a possible extension for up to two more years.

The Committee shall be responsible for the appointment of a Secretary [and a Frequency Manager] to support the Committee in its activities, and undertake any other activities the Committee may require.

4. Member Institutions of RAFCAP

Member institutions of RAFCAP – supporting the meetings and the Frequency Manager of the Committee – should be involved in radio astronomy, or related sciences.

New member institutions are accepted after consultation with RAFCAP and the existing institutions.

5. RAFCAP Modus Operandi

The Committee shall normally hold at least one plenary meeting per year at which all business items are considered. The committee meetings are convened by the RAFCAP Chairperson. Additional meetings or teleconferences are convened as appropriate.

The Committee may establish procedures as necessary to meet its mission.

The Committee, if it is deemed necessary, may draw up a set of detailed regulations for its *modus operandi*, in line with the Charter.

6. RAFCAP Finance

The costs of the Committee's meetings [and of the RAFCAP Frequency Manager] are financed by the member institutions.

Contributions from other bodies – such as national research agencies and institutes, or other institutions – may also be sought.

RAFCAP finances are regularly audited by one of the RAFCAP member institutions.

7. Reporting and Advising Activities of RAFCAP

The Committee reports, as appropriate, [in particular to the Directors' Committee in the Asia-Pacific region, and] to the RAFCAP member institutions.

James C. Lin

Wireless Transmission of Space Solar Power and Its Biological Implications

During the last ten years, interest in wireless transmission of solar electric power from a space station to Earth has grown in Japan and in the United States. Recently, the US government has commissioned a study by the National Research Council (NRC) to take a fresh look at current efforts in research, technology, and potential investment strategies [1].

The concept of solar-power satellites (SPS) and wireless power transmission (WPT) envisions the generation of electric power by solar energy in space, for use on Earth. The system would consist of an orbiting platform to gather solar energy and convert it to electric and microwave power in space. A microwave transmission system would be employed to send the electric power to Earth. A power receiving antenna (rectenna), on the ground or offshore, would convert and collect the transmitted microwave energy in a form of electricity suitable for the common electric utility distribution infrastructure.

In addition to providing a future energy source – to compete with other sustainable energy sources to meet the goal of providing sustainable energy for future growth and protection of the environment – SPS-WPT has the appeal of enhancing other space and commercial applications. Thus, SPS-WPT is turning into an increasingly viable candidate for development in space.

Brief History of Wireless Power Transmission

The idea of wireless power transmission began with Nikola Tesla at the start of the last century [2, 3]. Under the stimulus of an intense wartime research effort, microwave sources with considerable output power were rapidly developed [4], and it was discovered that microwaves having wavelengths of a few centimeters could be focused [5]. However, all such sources were reserved solely for military use during World War II. As the war ended, microwave sources became more widely available. Many investigators began exploring the use of microwave energy for industrial, scientific, and medical (ISM) applications. Brown and his colleagues [3, 6] pursued the possibility of using microwaves for wireless transmission of power, which had led to the successful demonstration of the flight of a microwave-powered scale model of a helicopter [7].

The transmission of electric power generated in space, using focused microwaves, was initially proposed in 1968 [8]. Since then, many variations of the concept have been proposed for satellite-collected solar energy to be used for human activities on Earth and in space. The basic concept and the context of its application essentially remain the same as originally proposed. More than three decades have passed since Glaser's first publication concerning power from space. While considerable progress has been made in solar cells and space transportation systems, a great deal of the research and development have been theoretical, and very little progress has been made on the basis of practical electric power systems on Earth.

Nevertheless, most of the concepts essential for SPS-WPT operation have been successfully demonstrated [9]. The accomplishments, to date, include the demonstration of point-to-point WPT; 30 kW of microwaves were beamed over a distance of one mile to a receiving antenna [10]; transmission of an 800-W microwave beam from a rocket to a free-flying satellite in space [11, 12]; and microwave-to-dc conversion efficiency of 82% or higher by the rectenna [10, 13].

DOE/NASA (the Department of Energy/National Aeronautics and Space Administration) extensively investigated the feasibility of SPS-WPT in the US during 1976-1980. The study concluded positively that research and development of SPS should proceed. It recommended that the program should be continued at a modest funding level, that further efforts should be directed at resolving or reducing significant uncertainties associated with microwave radiation effects and design considerations, and to continue

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some promising experiments. The study generated a Reference System Concept for Solar Power Satellites (for an example, see [14]). However, the study was interrupted for economic reasons, and because of funding priorities in the United States.

The 1979 Reference System involved placing a constellation of solar power satellites (5 × 10 × 0.5 km deep) in geostationary Earth orbits, each of which would provide 5 GW of power to major cities on the ground, using a 2.45 GHz microwave beam. Sixty such satellites of the Reference System were contemplated to deliver a total of 300 GW of generating capacity. The transmitting antenna was about 1 km in diameter. The power-receiving rectenna, on the ground, was a 10 × 13 km structure. Some researchers have proposed the use of higher frequencies, such as the similarly atmospheric-transparent 5.8 GHz, to reduce the large size of the transmitting and receiving antennas.

Recent Developments

However, the scenario may be changing. New technologies and business models are advancing the global economy at an unprecedented pace. They have also sparked the rise in consumption of fossil fuel and the hunger for electricity. The projected increase in greenhouse gases might be linked directly to global warming. The revolution in global economic development and energy demand is inducing profound challenges to the Earth's environment and human ecology. The finite supply and parochial nature of these energy sources, along with environmental concerns including waste management, are arguing more forcefully for SPS-WPT as a future energy source to compete with other sustainable energy candidates.

Recently, a strong case for reconsidering the space solar-power option has been made by some NASA personnel [16, 17], because new approaches may make it affordable. Major changes have occurred in technology, in the economic environment, and also in our perception of the global climatic effects of power generation and use during the past 20 years.

Some of these concerns were with us 20 years ago, but they are much stronger today. The growth in global population and the change in economic conditions have now brought the level of practicality of the space-power system to a much greater level than it has been before. It has been projected that during the coming 25 years, world population will grow by as much as 25%, while the world demand for electricity will double. (The world's population is projected by some to skyrocket to 10 billion people by the year 2050.) Using current technologies, this increasing use of electricity will inevitably lead to similar increases in the release of carbon dioxide, and escalating increases in the concentration of the "greenhouse gases" in the atmosphere. Meeting the goal of providing sustainable energy for future growth and protection of the environment, and supplying cheap electricity to meet basic needs, will be a daunting challenge. There is a clear need to pursue technologies that can enable dramatic increases in renewable energy production worldwide.

Space commerce has come of age. Billions of dollars are now being raised regularly for new space ventures. It is conceivable that the high-risk technologies needed to enable space solar-power systems will mature in the not-too-distant future, thus making possible continuing economic growth in the developing world and elsewhere.

A subtle reminder to undertake research and development to increase the various performance factors and production: although major advancements have occurred in technology, the present annual production in the world is several tens of megawatts, only a fraction of the 5 GW targeted in the Reference System. And, it would be close to the maximum production capacity of gallium arsenide (GaAs) solar cells and by all resources on Earth at the present time [15]. Thus, considerable progress still needs to be made in solar-cell technology and production in order for the Reference System of solar-power stations to be deployed by the US during the first half of this century.

Into the Space Age

In early 2001, Japan's Ministry of Economy, Trade and Industry (METI) announced ambitious plans to launch research for a solar-power-generation satellite in April, 2001, and to begin operating a giant solar-power station by 2040. The SPS will send electrical power in the form of microwaves back to Earth, with a lower intensity than those emitted by cellular mobile telephones. This program is expected to design and operate an SPS-WPT system that would ensure that the microwaves would not interrupt cellular mobile telephone and other wireless telecommunications services.

The planned satellite will be capable of generating 1 GW/s – equivalent to the output of a nuclear plant – in a geostationary orbit, about 36,000 km (22,320 mi) above the Earth's surface. The satellite will have two gigantic solar-power-generating wing panels, each measuring 3 × 1 km, with a 1 km-diameter power-transmission antenna between them. The power receiving antenna on the ground (several kilometers in diameter) would probably be set up in a desert or at sea.

NASA began conducting a Space Solar Power (SSP) Exploratory Research and Technology (SERT) Program in 1999. This program is aimed at defining new system concepts and the technical challenges involved in SSP; initiating a wide range of activities to test the validity of SSP strategic research and technology road maps; and to lay out potential paths for achieving all needed advances, over several decades, for the possible development of SSP technologies. No "show stoppers" have been identified. One important result of this $22 million program has been the identification of several new approaches, which apply low-energy, solid-state lasers for wireless power transmission, as an alternative to microwave approaches [18]. Additional funding for SSP research and technology appears to have been appropriated in NASA's 2001 fiscal-year budget.

Environmental and Health Concerns

A variety of environmental considerations and safety-related factors continue to receive consideration by the NASA team, albeit at a low priority level. To assure environmental health and safety, the SERT Program has limited the "center-of-beam" power densities to the range of 100-200 W/m^2 (10-20 mW/cm^2), for both microwave and visible-light transmission (corresponding to between 10-20% of the intensity of normal noontime summer sunlight, in the case of lasers). For WPT, the microwave power density is projected to be 1.0 W/m^2 (0.1 mW/cm^2) at the perimeter of the rectenna.

The assessment of the SERT Program by the National Research Council [1] has recommended more emphasis and expansion of its environmental, health, and safety efforts, in order to review the environmental, health, and safety hazards of the design, and to identify research if these hazards are not fully understood early in the program. It would also be of interest to examine the biological implications of SPS-WPT.

The 1979 Reference System, with a target power capacity of 5 GW, is planned to have a potential exposure of 250 W/m^2 (25 mW/cm^2) above the rectenna area. This drops off to about 10 W/m^2 (1.0 mW/cm^2) at a distance of 5 km from the rectenna's center. Beyond the perimeter of the rectenna, or 15 km, the sidelobe peaks would be less than 0.1 W/m^2 (0.01 mW/cm^2) at 2.45 GHz.

The ANSI/IEEE [19] standard for maximum permissible human exposure to microwave radiation at 2.45 GHz is 81.6 W/m^2 (8.16 mW/cm^2), averaged over six minutes, and 16.3 W/m^2 (1.63 mW/cm^2), averaged over 30 minutes, respectively, for controlled and uncontrolled environments. The controlled and uncontrolled situations are distinguished by whether the exposure takes place with or without knowledge of the exposed individual. This is normally interpreted to mean individuals who are occupationally exposed to the microwave radiation, as contrasted with the general public. Clearly, beyond the perimeter of the rectenna, the potential exposure, for either the CERT or Reference System, would be well below that currently permissible for the general public. The SPS-WPT system, proposed by Japan's METI, will be designed to have a ground-level microwave power density lower than that emitted by cellular mobile telephones. Cellular telephones operate with power densities at or below the ANSI/IEEE exposure standards [20]. Thus, public exposure to the SPS-WPT fields would also be below existing safety guidelines.

The danger of loss of control of highly focused beams may be minimized by tightly tuned phased-array techniques, and by automatic beam defocusing to disperse the power, in the event it occurs. Defocusing would degrade the beam toward a more isotropic radiation pattern, which would give rise to even lower power density on the ground [21]. At the center of the microwave beam, power densities would be greater than the permissible level of exposure for controlled situations. Except for maintenance personnel, human exposure would normally not be allowed at this location. In the case of occupationally required presence, protective measures, such as glasses, gloves, and garments, might be used to reduce the exposure to a permissible level. However, above the rectenna, where the power density is about 250 W/m^2 (25 mW/cm^2), research in support of the Reference System has found that some birds exhibit evidence of detection of the microwave radiation. This suggests that migratory birds, flying above the rectenna, might suffer disruption in their flight paths. Moreover, at higher ambient temperatures, larger birds seem to experience more heat stress than smaller ones, during 30 minutes of exposure [22]. This result is consistent with the knowledge that the larger birds, having a larger body mass, absorb a relatively greater quantity of 2.45 GHz microwave radiation than do the smaller birds. The additional heat – from microwave energy deposited inside the body – stresses the thermal regulatory capacity of the larger birds.

Summary

The cost for the construction and operation of an SPS-WPT system using today's technology is an order of magnitude higher than economically practical. But SPS-WPT is turning into an increasingly viable candidate as a future energy source, to compete with other sustainable energy candidates to meet the goal of providing sustainable energy for future growth and protection of the environment. In addition, new business models that structure SPS-WPT as an industrial commodity – where the solar power from space is delivered on demand to Earth-bound rectenna sites – could move the concept much further along in 15, 25, or 40 years.

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On behalf of the Local Organizing Committee,
Frans W. Sluijter, Chairman.

CONFERENCE REPORT

The First STEP-Results, Applications and Modeling Phase (S-RAMP) Conference

Sapparo, Japan, 2 - 6 October 2000

One of the programs organized by the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP), which followed on from the earlier Solar-Terrestrial Energy Program (STEP), is S-RAMP, the STEP-Results, Applications, and Modeling Phase (S-RAMP) program. S-RAMP is designed to capitalize on the vast data sets and powerful modeling techniques that were developed under STEP auspices, running from 1998 through 2002. S-RAMP aims at accomplishing three main goals:

1. Enable detailed understanding of Sun-Earth coupling mechanisms;
2. Facilitate effective information transfer between experimentalists, theoreticians, and modelers; and
3. Demonstrate the successful benefits of the STEP endeavor to funding agencies, the media, and the general public.

The first comprehensive conference of the S-RAMP program was held in the beautiful northern Japanese city of Sapporo during the period 2-6 October 2000, at roughly the mid-point of the five-year international program. This conference was convened with goals described above in mind. Besides enabling the effective flow of data and information throughout the wide S-RAMP community, this conference also emphasized the importance of conveying exciting science findings to the general public and to the media as well as to funding agencies. In so doing, we expect to maintain current support and generate new support to enhance our scientific programs, our cross-disciplinary studies, and the practical applications of this knowledge of the Sun-Earth system to various important areas in society.

The First S-RAMP Conference - with over 700 papers presented - was held in the Conference Center of the Hotel

Figure 1: Active discussions at symposia/workshops during the First S-RAMP Conference

Royton Sapporo and Sapporo Media Park. Some 580 scientists were registered attendees. There were 19 separate scientific symposia, three tutorial lectures, three workshops, and numerous affiliated side and splinter meetings. Clearly, the conference covered all aspects of solar-terrestrial physics, far too many topics to adequately address in a brief meeting report.

An important aspect of the S-RAMP activities, however, is the identification of intervals for detailed study. Two of the intervals formed the basis for sessions and workshops at the S-RAMP conference. The S-RAMP Steering Committee designated April-May 1998 as a special analysis interval. Extreme solar, geomagnetic and solar wind conditions were observed by an impressive international array of satellites and ground-based sensors. Multiple coronal mass ejections, large solar flares, and high-speed solar wind streams led to a powerful sequence of solar wind drivers of magnetospheric processes on Earth. One result of the combination of solar wind disturbances was the production of a deep, powerful and long-lasting enhancement of the highly relativistic electron population throughout the outer terrestrial radiation zone. Scientists associated with the Solar and Heliospheric Observatory (SOHO) collected impressive images of solar eruptions spreading out into space. Japan's Yohkoh satellite and NASA's TRACE (Transition Region and Coronal Explorer) satellite also recorded images of these disturbances. At geostationary altitude, NOAA's GOES-8 and -9 satellites measured solar X-ray flare emissions and monitored the influx of energetic electrons, protons and heavier ions into the magnetosphere. They also recorded magnetic storms in space as a complement to magnetograms recorded at ground observatories.

Space Weather Month is a month-long campaign interval during September 1999, conceived and coordinated under the auspices of the S-RAMP program. Its purpose is to study space weather and events from their initiation on the sun to their impacts at the Earth including effects on space-based and ground-based worldwide assets and assessment of the accuracy of forecasting techniques. Special features of the campaign include: broad international cooperation, as complete as possible coverage of the event through worldwide coordinated space and ground based observations (including maximized coverage by the ISTP program, the Oersted satellite and other spacecraft). Three scheduled Incoherent Scatter Radar world days (15-17 September 1999) encouraged involvement of the user communities and participation of the forecasting community.

Acknowledgments

Special thanks are due to the Program Committee and the Scientific Organizers led by Professor Y. Omura. It is also our great pleasure to express our deep thanks to the Local Organizing Committee chaired by Professor T. Araki. The Conference received generous assistance from many organizations and entities. The meeting was sponsored by SCOSTEP and the Japanese Ministry of Education, Science, Sports and Culture, in cooperation with the Committee on Space Research (COSPAR), the International Association of Geomagnetism and Aeronomy (IAGA), the International Association of Meteorology and Atmospheric Sciences (IAMAS), and the International Union of Radio Science (URSI). Also, the Society of Geomagnetism and Earth, Planetary and Space Sciences, the Astronomical Society of Japan, the Japanese Society for Planetary Sciences, and the Meteorological Society of Japan cooperated actively. The Conference was supported by the Hokkaido Prefecture Government, the City of Sapporo, the Sapporo International Communication Plaza Foundation, the Commemorative Association for the Japan World Exposition (1970), the Asian Office of Aerospace Research Development, Hokkaido Railway Company, Royton Sapporo, the Sapporo Television Broadcasting Co. Ltd, EC Inc., and FUJITSU. U.S. participation was supported by special grants from the National Science Foundation, NASA and the Air Force Office of Scientific Research.

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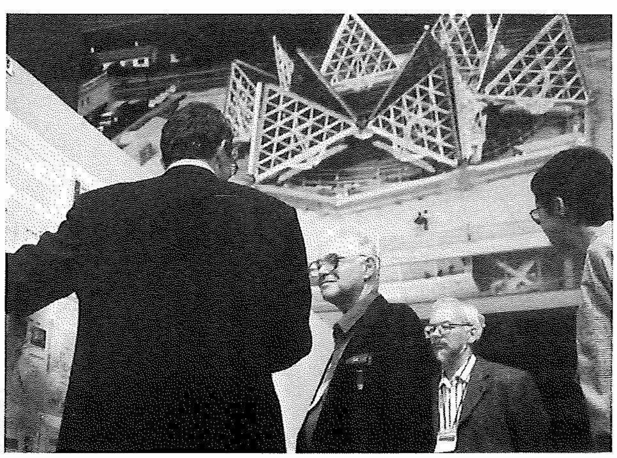

Figure 2: Poster sessions under a unique environment

Figure 3: Sumo play at the Opening Get-together

CONFERENCE ANNOUNCEMENT

EMC Zurich '03

Zurich, Switzerland, 18 - 20 February 2003

The 15th International Zurich Symposium and Technical Exhibition on Electromagnetic Compatibility will be held from February 18 trough 20, 2003 at the Swiss Federal Institute of Technology in Zurich (ETH Zurich), Switzerland. The expected attendance is about 1000 participants from over 40 countries.

The aim of the conference is to provide an efficient platform for the dissemination and the exchange of scientific-technical information concerning all aspects of the electromagnetic compatibility. Among the EMC Conferences EMC Zurich is the second largest but the most internationally oriented worldwide.

The Symposium is organized by the Communication Technology Laboratory and the Laboratory for Electromagnetic Fields and Microwave Electronics of the Swiss Federal Institute of Technology Zurich. Prof. Dr. R. Vahldieck and Dr. G. Meyer act as symposium president and symposium chairman, respectively. The technical program committee is again chaired by Dr. F. Tesche (Saluda NC, USA). As in the preceding years, the symposium is sponsored by the Swiss Electrotechnical Association (SEV/ASE).

A number of international and national professional organizations are cooperating, e.g. ITU, IEEE and URSI. As in the past URSI will sponsor again the participation of young scientists.

A total of about 135 carefully selected technical papers will be presented in 18 sessions devoted but not restricted to: Managerial aspects of EMC compliance, EMC measurement techniques in theory and practice, aspects of steady state (including time harmonic) as well as non-stationary EM environments, modeling for system-level EMC analysis, practical aspects of EMC on large systems, EMC issues at the chip and package levels, lightning and electrostatic discharge, EMC innovation, power system EMC, and EMC protection.

The sessions will cover virtually all "hot" topics and review the current status as well as future trends of EMC technology. It is planned to publish the full text of the presentations in the symposium proceedings and on a CD ROM.

As in previous symposia the program will not exclusively address experts. An introduction to EMC technology for newcomers will be offered by tutorial lectures and workshops. Once again, a number of national and international organizations use the opportunity of the symposium to hold open and closed meetings in coordination with EMC Zurich.

Contact Information

EMC Zurich '03
Dr. Gabriel Meyer, Symposium Chairman
ETH Zentrum, IKT – ETF
CH-8092 Zurich, Switzerland
Tel: +41 1 632 2793
Fax: +41 1 632 1209
Email: gmeyer@nari.ee.ethz.ch
http://www.emc-zurich.ch/

URSI CONFERENCE CALENDAR

URSI cannot be held responsible for any errors contained in this list of meetings.

June 2002

EUSAR 2002
Cologne, Germany, 4-6 June 2002
Contact : Dr. H. Schneider (FGAN/FHR), EUSAR 2002 Conference Office, Neuenahrer Str. 20, D-53343 Wachtberg, Germany, +49 228-9435-214, Fax +49 228-9435-627, E-mail : eusar2002@fgan.de

Spectrum Management for Radio Astronomy
Green Bank, West Virginia, USA, 8-14 June 2002
Contact: Dr. Darrel Emerson, Summer School on Spectrum Management, National Radio Astronomy Observatory, Green Bank, W VA, USA, E-mail: iucafchair@iucaf.org

CPEM 2002
Ottawa, Canada, 16-21 June 2002
Contact: CPEM 2002, National Research Council of Canada, Building M-19, Chemin Montréal, Ottawa ON K1A 0R6, Canada, Phone : (613) 993-7271, Fax : (613) 993-7250, E-mail: CPEM02@nrc.ca

EMC Wroclaw 2002 - 16th International Wroclaw Symposium on Electromagnetic Compatibility
Wroclaw, Poland, 27-30 June 2002
Contact : EMC Symposium, 51-645 Wroclaw 12, Box 2141 Wroclaw, Poland, Fax +48 71-372 8878, E-mail : emc@il.wroc.pl, http://www.emc.wroc.pl/

July 2002

Endogenous Physical Fields in Biology
Prague, Czech Republic, 1-3 July 2002
Contact: J. Pokorny, Symposium Office, Institute of Radio Engineering and Electronics, Chaberska 57, Prague 8, Czech Republic, Tel: +420 2 6881804, Fax: +420 2 6880222, Email: pokorny@ure.cas.cz, http://www.ure.cas.cz/events/epfb2002

August 2002

URSI General Assembly 2002
Maastricht, The Netherlands, 17-24 August 2002
Contact: Dr. Leon P.J. Kamp, Eindhoven University of Technology, Department of Applied Physics, P.O. Box 513, NL-5600 MB Eindhoven, The Netherlands, Tel: +31 40-2474292, Fax: +31 40-2445253, Email: URSI2002@tue.nl, http://www.URSI-GA2002.nl/

September 2002

EMC Europe 2002 - International Symposium on Electromagnetic Compatibility
Sorrentino, Italy, 9-13 September 2002
Contact: EMC Europe 2002 Secretariat, AEI Ufficio Centrale, Piazzale R. Morandi 2, 20121 Milano, Italy, Phone: +39-02-77790-205/218, Fax: +39-02-798817, E-mail: emceurope 2002@aei.it, http://www.aei.it/emceurope2002.html

October 2002

World Space Congress 2002, 34th COPSPAR Scientific Assembly
Houston, Texas, USA, 10-19 October 2002
Contact: COSPAR Secretariat, 51 bd de Montmorency, 75016 Paris, France, Tel: +33 1 4525 0679, Fax: +33 1 4050 9827, E-mail:cospar@cosparhq.org, Internet:http://www.copernicus.org/COSPAR/COSPAR.html

Getting the Most Out of the Radio Spectrum
London, United Kingdom, 24-25 October 2002
Contact : Getting The Most Out of the Radio Spectrum Secretariat, Event Services, Institution of Electrical Engineers, Savoy Place, London WC2R 0BL, Tel: +44 20-7344 5422, Fax: +44 20-7497 3633, E-mail: emaycock@iee.org.uk

November 2002

12th International Symposium on Antennas (JINA 2002)
Nice, France, 12-14 November 2002
Contact: Secrétariat JINA 2002, France Télécom R&D, Fort de la Tête de Chien, 06320 La Turbie, France, Fax: +33 4 9210 6519, E-mail: jina.cnet@wanadoo.fr, Internet: http://www.jina2002.com

APMC2002, Asia-Pacific Microwave Conference
Kyoto, Japan, 19-22 November 2002
Contact: Prof. Shozo Komaki, Chair, Steering Committee, c/o Realize Inc., 4-1-4 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan, Tel: +81-3-3815-8590, Fax: +81-3-3815-8529, Email: mweap mc@bleu.ocn.ne.jp, http://www.apmc-mwe.org

ISAR-3 - Third International School on Atmospheric Radar
ICTP Trieste, Italy, 25 November - 13 December 2002
Contact : Dr. Juergen Roettger, Max-Planck-Institut fuer Aeronomie, Max-Planck-Strasse 2, D-37191 Katlenburg-Lindau, Germany, Tel. +49 5556-979163, Fax +49 5556-979473, E-mail : roettger@linmpi.mpg.de

ISAP-i02, Intermediate International Symposium on Antennas and Propagation
Yokosuka, Japan, 26-28 November 2002
Contact: Prof. Kenichi Kagoshima, Chairperson, ISAP i-02, Ibaraki University, 4-12-1 Nakanarusawa, Hitachi, 316-8511 Japan, http://www.ieice.org/cs/ap/ISAP2002/

Supernovae
Valencia, Spain, 22-26 April 2003
Contact : Prof. Jon Marcaide, Dpto. Astronomia, Universidad de Valencia, E-46100 Burjassot, Valencia, Spain, Phone: +34-963983079, Fax: +34-963983084, E-mail: sne2003@reber.uv.es

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NEWS FROM THE MEMBER COMMITTEES

TURKEY

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This is to announce the 1st National Radio Science Conference, **URSI – TÜRKIYE'2002**, to be held in Istanbul, Turkey. The Faculty of Electrical & Electronics Engineering, Istanbul Technical University (I.T.U.) will host the conference over the period 18 - 20 September 2002. The conference will provide a valuable opportunity to exchange and update information and stimulate discussions on current and future research activities in the fields of the committee.

Program

The technical program will consist of invited and submitted papers covered by the URSI commissions A-K:

A) Electromagnetic metrology
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Submission of one page abstract	13 May 2002
Notification of acceptance and authors kits	21 June 2002
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Awards For Young Scientists

URSI – TURKEY wishes to encourage the participation of young scientists. They should have a paper, of which he/she is the principal author, submitted and accepted for presentation at the Conference.

Contact

All inquiries concerning the URSI – TÜRKÝYE'2002 Conference should be addressed to:

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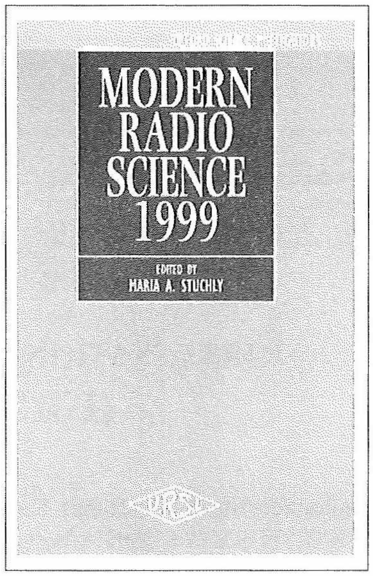

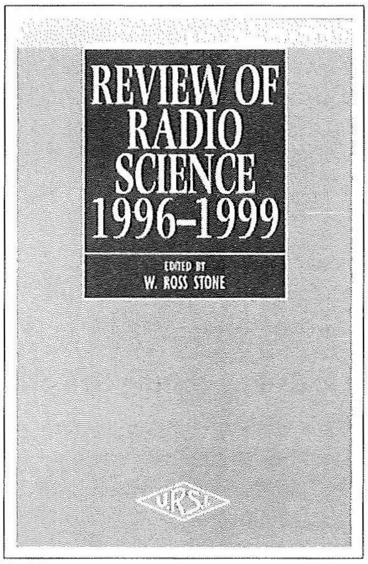

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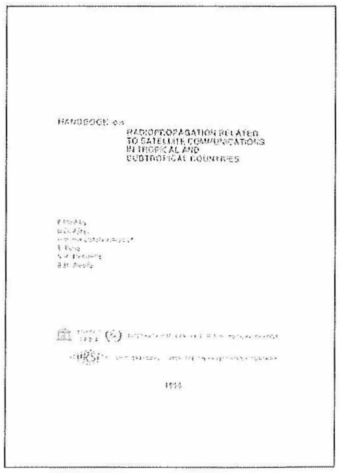

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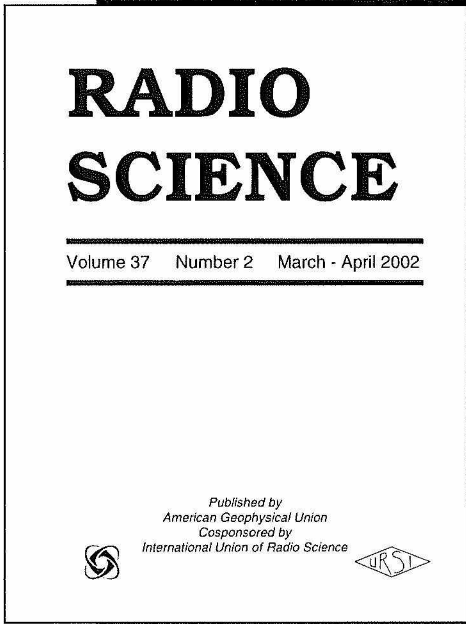
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AIMS AND SCOPE

The *Journal of Atmospheric and Terrestrial Physics* (JASTP) first appeared in print in 1951, at the very start of what is termed the "Space Age". The first papers grappled with such novel subjects as the Earth's ionosphere and photographic studies of the aurora. Since that early, seminal work, the Journal has continuously evolved and expanded its scope in concert with - and in support of - the exciting evolution of a dynamic, rapidly growing field of scientific endeavour: the Earth and Space Sciences. At its Golden Anniversary, the now re-named *Journal of Atmospheric and Solar-Terrestrial Physics* (JASTP) continues its development as the premier international journal dedicated to the physics of the Earth's atmospheric and space environment, especially the highly varied and highly variable physical phenomena that occur in this natural laboratory and the processes that couple them. The *Journal of Atmospheric and Solar-Terrestrial Physics* is an international journal concerned with the inter-disciplinary science of the Sun-Earth connection, defined very broadly. The journal referees and publishes original research papers, using rigorous standards of review, and focusing on the following: The results of experiments and their interpretations, and results of theoretical or modelling studies; Papers dealing with remote sensing carried out from the ground or space and with in situ studies made from rockets or from satellites orbiting the Earth; and, Plans for future research, often carried out within programs of international scope. The Journal also encourages papers involving: large scale collaborations, especially those with an international perspective; rapid communications; papers dealing with novel techniques or methodologies; commissioned review papers on topical subjects; and, special issues arising from chosen scientific symposia or workshops. The journal covers the physical processes operating in the troposphere, stratosphere, mesosphere, thermosphere, ionosphere, magnetosphere, the Sun, interplanetary medium, and heliosphere. Phenomena occurring in other "spheres", solar influences on climate, and supporting laboratory measurements are also considered. The journal deals especially with the coupling between the different regions. Solar flares, coronal mass ejections, and other energetic events on the Sun create interesting and important perturbations in the near-Earth space environment. The physics of this subject, now termed "space weather", is central to the Journal of Atmospheric and Solar-Terrestrial Physics and the journal welcomes papers that lead in the direction of a predictive understanding of the coupled system. Regarding the upper atmosphere, the subjects of aeronomy, geomagnetism and geoelectricity, auroral phenomena, radio wave propagation, and plasma instabilities, are examples within the broad field of solar-terrestrial physics which emphasise the energy exchange between the solar wind, the magnetospheric and ionospheric plasmas, and the neutral gas. In the lower atmosphere, topics covered range from mesoscale to global scale dynamics, to atmospheric electricity, lightning and its effects, and to anthropogenic changes. Helpful, novel schematic diagrams are encouraged. Short animations and ancillary data sets can also be accommodated. Prospective authors should review the *Instructions to Authors* at the back of each issue.

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