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INTERNATIONAL
UNION OF
RADIO SCIENCE

U.R.S.I.

UNION
RADIO-SCIENTIFIQUE
INTERNATIONALE

INFORMATION BULLETIN
D'INFORMATION

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URSI, c/o University of Gent (INTEC)
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Contents

URSI ACCOUNTS 1993

The Balance Sheet and the Income and Expenditure Accounts of URSI for the year ended 31 December 1993 are reproduced below.
The original accounts have been audited by Van Poyer & Cie, Réviseurs d'Entreprises, Brussels, at the end of March 1994.

As this is my first report as Treasurer I have first to express the thanks of URSI to Dr Pierre Bauer the outgoing Treasurer for his guardianship of our funds over the last triennium and to also express the thanks of URSI to the former Secretary General Professor Jean Van Bladel for his day-to-day guardianship of the accounts.

The Balance Sheet and the Income and Expenditure Accounts of URSI for 1993 show that URSI's finances continue to remain robust and this has permitted Council to allocate $12,000 per Commission over the next three years to reflect the expanding activities of our ten Commissions. The reserves of URSI are divided between assets held in the USA and in Europe and the Board will continue to monitor this arrangement so as to safeguard URSI's financial future.

P.J.B. Clarricoats, Treasurer

INTERNATIONAL UNION OF RADIO SCIENCE (URSI)

BALANCE SHEET : 31 DECEMBER 1993

ASSETS		
Dollars		$
Banque Degroof	35,201.63	
Merrill Lynch WCMA	47,594.31	
Smith Barney Shearson	0.61	
Traveller Cheque	1,000.00	
		83,796.55
Belgian francs		
Banque Degroof	14,084.31	
Générale de Banque	8,803.32	
		22,887.63
Investments		
Demeter Sicav shares	20,547.38	
Rorento Units	111,806.17	
Merrill Lynch Fund	60,019.95	
Aqua Sicav	57,783.18	
Smith Barney Shearson Utilities Fund	81,764.00	
Reinvestment S.B. Shearson Utilities	6,081.50	
Smith Barney Shearson Grade Bond	49,300.00	
Reinvestment S.B. Shearson Grade Bond	2,695.05	
		389,997.23
Other		
Petty cash	312.11	
Debitors	214.25	
		526.36
Total Assets		497,207.77
		========
Less creditors		
IUCAF	18,946.94	
IUWDS	5,189.73	
Audit fees	1,549.30	
Salary and Social Security	3,699.32	
		(29,385.29)
Balth van der Pol Medal Fund (1)		(13,381.97)
NET TOTAL OF URSI ASSETS		454,440.51
		========

URSI ACCOUNTS 1993

The net URSI Assets are represented by :

		$
Closure of Secretariat :		
Provision for Closure of Secretariat		19,185.21
Scientific Activities Fund :		
Scientific Activities in 1994	60,000.00	
Young Scientists in 1994	30,000.00	
		90,000.00
XXIV General Assembly Fund during 1996 :		
Scientific	-	
Young Scientists	-	
Organization	-	
		109,185.21
Unallocated Reserve Fund		345,255.30
		454,440.51
		========

Statement of Income and Expenditure for the year ended 31 December 1993

I. INCOME

		$
Grant from ICSU Fund		21,200.00
Contributions from Member Committees		209,005.73
Sales of Publications		22.54
Bank Interest		19,245.76
Gain of Exchange		257.95
Other Income		27,520.48
	Total Income	277,252.46
		========

II. EXPENDITURE

a) Scientific Activities		140,163.49
General Assembly - Organization	3,180.13	
General Assembly - Scientific	42,163.98	
General Assembly - Young Scientists	40,507.30	
Symposia/Colloquia/Working Groups	40,565.10	
Representation at scientific meetings	6,930.08	
Grants to organizations	6,816.90	
b) Routine Meetings		
Bureau/Executive committee		16,316.58
c) Publications		35,922.93
d) Administrative Expenses		70,929.54
Salaries, Related Charges	41,655.75	
General Office Expenses	10,745.83	
Office Equipment	4,649.69	
Accounting and Audit Fees	9,296.90	
Bank Charges	4,571.37	
e) ICSU Dues		5,953.00
	Total Expenditure	269,285.54
		========

	$
Excess of Income over Expenditure	7,966.92
Accumulated Balance at 1 January 1993	461,973.81
Balance at 31 December 1993	469,940.73
Appreciation of Belgian Franc	-15,500.22
Accumulated Balance at 31 December 1993	454,440.51
	========

Rates of exchange :

1 January 1993 : $1 = 33,00 BF
31 December 1993 : $1 = 35,50 BF

Observation :

The account indicated with (1) is represented by :
- 376 Rorento Shares : market value on December 31, 1993 = 19,428$

Market value of investments on December 31, 1993 ($1 = 35,50 BF) :

- DEMETER SICAV :	39,618.59
- RORENTO (2) :	335,885.77
- MERRILL LYNCH	65,861.00
- AQUA-SICAV :	63,672.20
- SMITH BARNEY SHEARSON :	140,466.06
	645,503.62

(2) including the 376 Rorento of v. d. Pol Fund

APPENDIX
Detail of Income and Expenditure

		$
I. INCOME		
Other Income :		
Royal Society of London	1,531.83	
EMC Symposium	750.00	
ISSSE Symposium	4,982.50	
Spectrum Management	3,994.00	
Profit on Realisation Alpine Shares	13,914.94	
Profit on Realisation Aqua-Sicav	2,347.21	
		27,520.48
II. EXPENDITURE		
Symposia/Colloquia/Working Groups :		
START	2,600.00	
ICC'93	1,000.00	
ISAE'93 - Nanjing	1,500.00	
Ravenscar	2,000.00	
Air Sea Interface	2,000.00	
Int. Microwave	5,000.00	
IGARSS'93	5,000.00	
Electr. Medicine - Rome	1,000.00	
Theoretical Physics - Trieste	6,665.10	
ICPIG	800.00	
ISSSE'95	13,000.00	
		40,565.10
Grants to Organizations :		
Radio Science Press	2,816.90	
Contribution URSI to FAGS	2,000.00	
Contribution URSI to IUCAF	2,000.00	
		6,816.90

URSI ACCOUNTS 1993

Publications :		
Radio Science Journal	1,500.00	
Bulletin No 263	2,453.83	
Transportation Cost	2,730.54	
Bulletin No 264	1,179.13	
Transportation Cost	39.77	
Bulletin No 265	1,352.14	
Radio Science Press	22,519.16	
Transportation Cost	1,424.87	
Bulletin No 266	1,189.01	
Transportation Cost	1,534.48	
		35,922.93

BOOKS PUBLISHED BY URSI CORRESPONDENTS

Microwave and Geometrical Optics

by Dr. S. Cornbleet, Academic Press 1994, 640 pp., ISBN 012 189 651 X

Chapter 1: The single surface of reflection or refraction

Hamilton's fundamental laws of reflection and refraction, conical reflectors and the single surface lens, the zero distance phase front, Damien's inversion theorem.

Chapter 2: Double reflector antennas

Sub-reflectors for the sphere and paraboloid, application of Damien's theorem to reflectors, phase and amplitude distributions and subreflector design by a series of generic curves, general theory of offset double reflector antennas, methods of solution, survey of published treatments.

Chapter 3 : Lenses and Phase Corrected Reflectros

Design of lenses using Damien's theorem, general lenses for phase and amplitude distributions, Abbe sine condition, design of lenses by a series of generic curves, waveguide lenses, wide angle scanning lenses and lens-reflectors, a lens transformation hypothesis.

Chapter 4: Ray-Tracing in Non-Uniform Media

Ray equations for Cartesian, cylindrical, spherical and axisymmetric verying refractive indices, the statified linear medium, randomes, the spherical lenses, Maxwell fish-eye and Luneburg lenses, beam splitting lenses, the inversion of spherical media and rays, transformation of spherical lenses into geidesic lenses and generalizations arising, conical media and waveguide horns.

Chapter 5: Scalar Diffraction Theory of the Circular Aperture

General diffraction theory, Hankel and Lommel transforms, the circle polynomials of Zernike, Neumann series description of the radiation pattern, application to phase and amplitude distributions, zoned apertures, beam shaping using Dini, Struve and Schlomilch series descriptions, the inverse problem.

Chapter 6: Polarization

The polarization ellipse, the Pointcare sphere, Stokes, Jones and Mueller matrices, transformation of polarization through consecutive gratings, quaternion and spin matrix representation, radar polarimetry.

Chapter 7: Fields, Rays and Trajectories

Quaternion and b-quaternion description of the Maxwell field, definition of the optical field by 2 scalar "Baterman" potentials, application to optical ray systems in regular media, comparison with the natural trajectories of physics, the conformal invariance of the electrmagnetic field, derivation of the inversion property of the spherical non-uniform lenses and rays.

Appendix I: The laws of reflection and refraction, fifteen applicable formulation of Snell's laws.

Appendix II: The circle polynomials, Jacobi polynomials, Bessel and associated Bessel functions, Anger-Weber functions, orthogonal polynomial series.

Appendix III: Geometrical curves, formulae and form, involutes and evolutes, applications of Abel's integral.

Appendix IV: Quaternions and bi-quaternions, spin matrices, the rotation and other relevant groups.

IWG-TDWM

A meeting of the Inter-Commission Working Group on Time Domain Waveform Measurements [IWG—TDWM] was convened on Friday, August 27 at 1:00 p.m.. The meeting was attended by 17 persons representing various commissions.

It was resolved at the meeting that (see Resolution U.14) :

1. The IWG—TDWM should continue for another three years, if approved by the Council.
2. T.K. Sarkar should continue as Chair of the IWG-TDWM, if approved by the Council. No Vice-Chair was proposed.
3. The IWG-TDWM should try to organize joint sessions in the following areas:
   (a) Transient radar (both classical and subsurface) and signal analysis. It is anticipated that Commissions A,B,C, and E would be involved. Dr. Carl Baum (of Com. E) is already organizing a session on transient radar at the international conference EUROEM/NEM/HPEM'94 at Bordeaux.
   (b) Waveform characterization on printed circuits. Commissions A,B,D, and E would be involved.
   (c) Time Domain measurement system calibration . This topic would involve commissions A and B.

T. K. Sarkar, Chair

Report on Activities of Inter-Union Organizations

IUCAF

1. **Dr. Robinson prepared a report on the most recent activities of the IUCAF.** The essential points of this report are summarized below :

   "IUCAF, the Inter-Union Commission on the Allocation of Frequencies to Radio Astronomy and Space Science, was set up in 1960 by URSI, IAU and COSPAR. Its brief is to study and coordinate the requirements for radio frequency allocations for radio astronomy, space science and remote sensing in order to make these requirements known to the national and international bodies responsible for frequency allocations. IUCAF also takes action aimed at ensuring that harmful interference is not caused to radio astronomy, space science or remote sensing (operating within the allocated bands) by other radio services. It has to be particularly vigilant about radio transmissions from aircraft or space vehicles.

   IUCAF has maintained its network of Correspondents in 35 countries to interact with national authorities responsible for radio frequency allocations.

   During the period February to November 1992 it held meetings in Torremolinos (Spain) and Paris (France) and took part in :

   - The ITU World Administrative Radio Conference (Spain, 3 February - 4 March 1992). The "Final Acts" of WARC-92 are a binding international treaty on the member countries of ITU. In these "Acts" the status of space research, earth exploration and radio astronomy has been significantly enhanced relative to other users of the radio spectrum from 137 MHz to 3 GHz and above 13.5 GHz. Delegates from 125 countries at the WARC clearly recognized the importance of scientific use of the radio spectrum in the face of increasing pressures from telecommunications, broadcasting, navigation and military interests, particularly telecommunications and broadcasting transmissions from satellites.
   - Meetings in Moscow (June 1992) with the Russian Administration of the GLONASS Satellite Navigation System and the Russian Scientific Council for Radio Astronomy.
     Harmful interference to radio astronomy observations of the important 1612 MHz line of the Hydroxyl (OH) radical as well as the OH lines at 1665 and 1667 MHz are caused by emissions from the 14 GLONASS navigation satellites launched so far.
   - An IAU/ICSU/UNESCO Exposition in Paris (July 1992) on Adverse Environmental Impacts on Astronomy.
   - Discussions with Space Frequency Coordination Group (SFCG) in Sydney (October-November 1992).
     IUCAF also provided input papers to CCIR meetings of Study Group 7 (Scientific Services) in Geneva and Study Group 8 (Mobile Satellite Communications) in Tokyo.

2. Statement of Income and Expenditure for the year ended 31 December 1992

INCOME (in USD)
Contribution from :

- URSI	3,000.00	
- ICSU	3,100.00	
- IAU-1991-92	4,000.00	
TOTAL INCOME		10,100.00

EXPENDITURE (in USD)

- Expenses DOUBINSKY	4,200.00	
- Expenses SWARUP	2,400.00	
- Expenses THOMPSON	620.00	
- Expenses ROBINSON	3,410.00	
TOTAL EXPENDITURE		10,630.00

Excess of Expenditure over Income for the year	530,00
Accumulated Balance at 1 January 1992	17,431.94
Accumulated Balance at 31 December 1992	16,901.94

Rates of exchange
1 January 1992 : $1 = BEF 33,00
31 December 1992 : $1 = BEF 33,00

3. Meeting of IUCAF members and correspondents present in Kyoto, on 27 August 1993

The following items were discussed (Resolution U.18) :

1. (a) Negotiations with the Russian Administration to change the carrier frequencies of the GLONASS navigation satellites will continue in Moscow on 1-5 November 1993. On the basis of joint tests carried out in November 1992 the GLONASS system could use 12 carrier frequencies in place of the existing 24. The highest carrier frequency would be 1608.75 MHz. Interference to the Radio Astronomy Band 1610.6 - 1613.8 MHz would be reduced by more than 20 dB, as shown in the tests in November 1992 [Ref. : ITU Radiocommunication Study Group Doc. 7D/TEMP/ 17-E of 5 April 93].

1. (b) A high-powered Russian Delegation will be in Australia from 1 to 5 September 1993 and in Japan from 6 to 10 September 1993 to negotiate IFRB coordination of the GLONASS system with the Australian and Japanese governments. IUCAF member Dr. J.B. Whiteoak will take part in the Australian meeting while IUCAF member Dr. M. Ishiguro is in touch with the Japanese Ministry. We plan to advise Dr. Ishiguro of the status of the negotiations to be reached this week in Australia.

2. Concerning INMARSAT plans for Mobile Satellite Communications in Europe, IUCAF has had Dr. R.J. Cohen and Dr. T. Spoelstra active on a CEPT Project Team (SE17) to set sharing constraints for MSS land mobiles in the band 1610-1626.5 MHz. The Project Team has agreed on Coordination Distances of 100 km around Radio Astronomy Observatories for Land Mobile Uplinks to MSS satellites. Also, limits of -125 dBW/4 kHz have been set on out-of-band emissions from land mobile uplinks to MSS satellites.
The MSS satellite downlinks have secondary ITU allocations and must not interfere (Footnote 733E of Radio Regulations) with the primary allocation to Radio Astronomy in the band 1610.6-1613.8 MHz [WARC-1992].
3. IUCAF discussed preparations for future World Radio Conferences (WRC-93, WRC-95 and WRC-97). Two IUCAF observers will attend WRC-93 in Geneva from 15 to 19 November 93. There is particular concern about a proposal from CEPT countries proposing active services in bands which are currently exclusively passive (e.g. 1400-1427 MHz hydrogen line band) for Mobile Satellite use.
4. A proposed URSI Resolution was discussed. This was later supported by Commission J (see Resolution U.20).
5. Confidentiality of IUCAF Documents was discussed. It was agreed that all numbered IUCAF Documents should have unrestricted circulation.
6. IUCAF discussed the work of the Panel on Adverse Environmental Impacts on Astronomy, including :
   (a) The exposition held at UNESCO Headquarters in Paris in July 1992.
   (b) The recent Space Billboard proposal by Space Marketing Incorporated of Atlanta, Georgia. This proposes a 1000 m x 400 m Space Billboard in low earth orbit (≈ 300 km) in 1996.
7. An ERO/CEPT document was tabled which pointed to the commercial value of the 36GHz of passive spectrum allocated by the ITU below 265 GHz. This was quoted as 15% of the spectrum. This will be challenged at CEPT level by Dr. T. Spoelstra and Dr. R.J. Cohen.
8. IUCAF discussed possible involvement in a series of presentations by the ITU Voluntary Group of Experts in 1993 and 1994. IUCAF had been alerted to these meetings by Dr. Struzak of ITU.

B.J. Robinson, Chair

International Council of Scientific Unions (ICSU)

24th General Assembly and Related Meetings

Santiago, Chile, October 1-8, 1993

The 24th General Assembly of ICSU was held at the invitation of the Chilean Academy of Sciences. It was ICSU's first general assembly in the southern hemisphere. A full report on this gathering of about 250 participants from ICSU's 92 national scientific members, 20 unions and numerous associate members and interdisciplinary bodies will be issued by ICSU. This report is on only those matters perceived to be of interest to URSI.

1. 31st General Committee Meeting, Oct. 1-2

The general committee consisted of eight members of the ICSU board, 20 union members and 13 national scientific members. This meeting and the general assembly were chaired by ICSU president M.G.K. Menon. Reports on the ICSU interdisciplinary committees reviewed since the 1992 general committee meeting were presented. The two of direct interest to URSI were on SCOSTEP (Solar Terrestrial Physics) by a panel chaired by Michel Petit, ICSU treasurer, and COSPAR (Space Research) reviewed by a panel chaired by your URSI representative.

Because of their overlapping interests some reviewers proposed merging SCOSTEP with IAGA or COSPAR. However the unique role which SCOSTEP successfully fulfils, especially through its STEP program, was pointed out and the recommendation to continue SCOSTEP as a separate entity was accepted.

COSPAR has some overlapping interests with the IAU, IUGG and URSI and there have been past occasions where better coordination would have been desirable but lately this situation has improved. COSPAR has undergone major changes in its charter following the end of its domination by USA and USSR rivalry in space research. It has been a very successful organization and it is now open to broader participation by space scientists everywhere. The conclusion that COSPAR is even more relevant now than before was accepted by ICSU.

"Informatics" or computer sciences are not represented by a union within ICSU. There was some discussion as to whether and how this should be brought about. The International Federation of Information Processing, presently a scientific associate, would be approached on this matter.

ICSU vice president, W.E. Gordon, reported the work of the joint group on data to encourage ICSU's data collecting agencies CODATA, FAGS, WDC and IGBP-DIS, to establish ICSU policy on data issues. CODATA has agreed to do this.

2. Committee on Science and Technology in Developing Countries (COSTED). Plenary Meeting Oct. 4.

COSTED was formed by ICSU in 1966 to encourage science and technology in developing countries. In 1990 it reorganized to act as an advisory group to ICSU on ICSU activities in developing countries and on how these relate to other international efforts. It maintains regional secretariats in Accra, Caracas and Madras. With only 9 national members it recently solicited representatives from each union. As I was available to attend this plenary meeting I became the URSI representative. ICSU activity in developing countries occurs mainly through the unions. URSI, for example, has its young scientist program and its contribution to the program of the Third World Academy of Sciences COSTED has provided some of our travel costs for young scientists from developing countries. A handbook on "Activities on ICSU Bodies for Developing Countries" (1993) prepared by COSTED reports this. The COSTED plenary included a seminar on "The Role of Science and Technology Education in Capacity Building in Developing Countries", arranged in coordination with the ICSU Committee on the Teaching of Science (CTS).

3. 24th General Assembly, Oct. 4-8

The opening ceremonies and reception on the evening of October 4 included interesting talks on the relative youth of science in Chile and in Latin America in general. This was followed by 3 1/2 days of business meetings including a day of interdisciplinary scientific sessions.

3.1 Membership

ICSU admitted three new union members: International Union of Anthropological and Ethnological Sciences (IUAES), International Society of Soil Science (ISSS), International Brain Research Organization (IBRO). With these admissions, expansion of ICSU into areas of the social sciences continues and seems to begin in the agricultural and medical sciences. The basic premise is that ICSU represents the science, but not the practice of the applied sciences. Engineering is not represented but engineering science is through URSI, IUTAM, IUPAC, etc.

Eight new national scientific bodies became members of ICSU: Croatia, Czech Republic, Nepal, Panama, Singapore, Slovakia, Swaziland and Togo, bringing the total national membership to 92.

3.2 Finances

ICSU dues have been increasing at the rate of 5% p.a. since 1991, or somewhat less if inflation is taken into account. ICSU's treasurer recommended an increase of 8.2% p.a. over the next three years to restore funding of union projects to previous levels, to support projects of the new union members and to undertake new initiatives. National representatives of countries paying the largest dues were unwilling to accept this and the dues increase recommended by the general assembly finance committee (of which I was a member) and accepted by the general assembly was 5% in 1995 and 1.5% and 2.5% over the OECD inflation rate in 1996 and 1997.

URSI may now select its level of membership. We chose a dues category corresponding closest to the present level of URSI dues ($7,884 in 1993) and these dues will increase correspondingly. URSI, like other unions, receives several times this amount back in grants from ICSU.

3.3 Resolutions

URSI sponsored one of the 13 ICSU resolutions of this general assembly. This was based on an almost identical resolution at the Kyoto URSI general assembly. On electromagnetic pollution: ICSU "urges governments and the ITU to allocate a frequency spectrum only to those telecommunications services which must radiate electromagnetic energy and to avoid allocating frequency spectrum in situations where other technologies such as guided waves may used".

IAU sponsored a related ICSU resolution urging governments and national and international agencies to preserve an environment for sensitive astronomical studies by taking all necessary steps to prevent the use of solar reflectors for commercial advertising in space.

ICSU also expressed concern for the support of basic sciences, asking its national members to communicate to decision makers and to the public at large the importance of basic science as a long term investment for the benefit of society.

3.4 ICSU History

As one of the four original members of the International Research Council (1919) which disbanded in 1931 to become ICSU, URSI has a prominent role in the history of ICSU. This emerged in the lecture by ICSU historian F. Greenaway, who had been sent material on URSI, for the history of ICSU which he is writing.

3.5 Scientific Sessions

Parallel scientific sessions each with several speakers were held on the following topics:

i. Biodiversity Convention and Beyond
ii. El Nino and Related Phenomena
iii. Population and Human Reproduction
iv. Ozone Depletion and UV Damage
v. Science and Future Food Security
vi. Megatelescopes in Chile
vii. Scientific Aspects of National Disasters
viii. Climate Convention and Beyond

Topic vi, which I reported for ICSU, was mainly on several 4m diameter lightweight optically active reflectors being built or planned for observatories in NE Chile, the main center for optical astronomy in the S. hemisphere. I attended also the session on El Nino.

These scientific sessions were very interesting and most of us there would have appreciated the opportunity to attend more than just one each of the first and last four topics.

3.6 Elections

The 1993-96 executive board of ICSU is :

President:	J.C. Dooge (Ireland)
Vice Presidents:	H.A. Mooney (USA)
	Sun Honglie (China, Beijing)
Secretary General:	L.J. Cohen (UK)
Treasurer:	M. Petit (France)
Past President:	M.G.K. Menon (India)

plus six ordinary members announced at the following general committee meeting.

The new president was chosen in 1990 as "president elect", a position which no longer exists. The previous executive board selected the above nominees from amongst the nominations from union and national members. Generally no other names are submitted or resubmitted later and election is by acclamation, but on this occasion another nomination appeared and there was an election for secretary general.

Selection of the 16 new members of the ICSU general committee from the 27 nominees was by a nominating committee chaired by M.G.K. Menon. Those not selected could be renominated from the floor, but none were. The superficiality of this "election" was questioned, but it was according to ICSU statutes.

3.7 25th General Assembly

A preliminary invitation has been received by Thailand for 1996.

4. 32nd General Committee Meeting, Oct. 8

The main purpose of this meeting was to "elect" the ordinary members of the executive board from the nominees of the union and national members. Those selected by the nominating committee chaired by M.G.K. Menon were:

D.A. Akyeampong, Ghana
I. Lang, Hungary
K. Thurau, Germany
R. Colwell, (IUMS) USA
H. Moritz, (IUGG) Austria
J. Palis, (IMU) Brazil

The issue of "elections" arose again and president J. Dooge promised that this would be on the agenda of the next meeting of the statutes committee.

The 33rd meeting of the ICSU general committee will be in Morocco, Oct. 13-15, 1994.

5. Concluding Remarks

URSI president Pierre Bauer is now your representative to ICSU. My three year involvement with ICSU was most interesting and enjoyable, but with an ICSU meeting or two required for orientation, only in the last year was it possible for me to contribute to ICSU. That must be the experience of most general committee members. With very limited resources and a great deal of voluntary participation this organization has been remarkably effective in initiating major intedisciplinary programs (IGBP), helping influence governments and world opinion on important science issues (UNED), advising governments on their science organization (Hungary, Russia) as well as fostering a myriad of interdisciplinary science activities between unions. There is so much that could be done and will need to be done that ICSU has great future possibilities provided adequate support from governments and the unions is forthcoming. URSI, with its expertise in geophysical probing and telecommunications sciences, has traditionally been very active within ICSU and should continue to be so.

E.V. Jull

NEWS FROM THE MEMBER COMMITTEES

Egypt

NRSC'95 : TWELFITH NATIONAL RADIO SCIENCE CONFERENCE

March 21-23, 1995, Alexandria, Egypt

The first call for papers for this annual conference has just gone out. Topics solicited cover URSI commission subject areas.

Prospective authors are requested to submit four copies of the complete manuscript of a maximum of eight pages (additional charge is requested for more pages) to:

Prof. Dr. Ibrahim Salem
Academy of Scientific Research and Technology
101 Kasr El-Eini street, Cairo, Egypt

Or to:

Prof. Dr. Said e. El-Khamy
EE-Department, Faculty of Engineering
Alexandria University
Alexandria, Egypt

Deadlines: submission of manuscript: October 15th, 1994.
Notification of acceptance: 15 December, 1994.
Submission of camera-ready mats : 15 January, 1995.

In view of the URSI Electromagnetic Theory Symposium, recently held in St. Petersburg, Russia (23-26 May 1994), we reproduce below a report of the URSI Electromagnetic Theory Symposium (6-16 September,1971) by Professor J.R. Wait. This also complements Professor T.B.A. Senior's report in the December 1993 URSI Bulletin on the previous URSI Electromagnetic Theory symposium.

Following an invitation from the U.S.S.R. Academy of Sciences, forwarded to me via the U.S.A. National Academy of Sciences, I attended the URSI symposium on Electromagnetic Wave Theory in Tbilisi. My brief report on the meeting is attached.

In addition to participation in the Tbilisi meeting, I also visited briefly the following institutes:

1 Laboratory for Electromagnetic Wave Theory in Copenhagen (Sept. 5th)
2 Institute of Radio Engineering and Electronics in Moscow (Sept. 7th)
3 Moscow State University (Sept. 7th)
4 Institute of Radio Wave Propagation and the Ionosphere near Moscow (Sept. 16th)
5 Professor L.L. Vanyan of the Soviet Geophysical Committee in Moscow (Sept. 16th)

The 2-week trip was extremely useful in that it gave me an over-all view of the tremendous effort in electromagnetics now evident in the U.S.S.R. They seem to have no qualms about the relevance of such research in a country with an expanding technology. Also I gathered that graduates with such training had no difficulties finding assignments to national institutes in the general fields of radio science and telecommunication.

Electromagnetics in Tbilisi

The International Symposium on Electromagnetic Wave Theory was convened in Tbilisi, U.S.S.R. from September 9 to 15, inclusive.This was the seventh in a series of such symposia sponsored by the International Union of Radio Science (URSI). Previous ones were held at Montreal (1953), Ann Arbor (1955), Toronto (1959), Copenhagen (1962), Delft (1965) and Stresa (1968). The arrangements for the Tbilisi meeting were made by the Soviet National Commitee of URSI, the Academy of Sciences of the Georgian SSR, and the Institute of Radio Engineering of the U.S.S.R. Academy of Science in Moscow. Key individuals in te organizing and program committees included Prof. L.A. Vainstein (President), Dr. V.I. Aksenov, Dr. M.V. Persikov, Prof. V.D. Kupradze, Dr. V.V. Shevchenko, all of teh U.S.S.R. and Prof. L.B. Felsen of the U.S.A.

In the previous symposia, the Soviet participation was nominal in spite of their significant contributions in electromagnetic theory. At Tbilisi, the situation was rectified. Roughly 70% of the papers were by Soviet authors, and more than 200 of the 300 participants were Soviets. The greatest number of foreign delegates were from Italy, U.S.A., Poland, Denmark, The Netherlands and Czechoslovakia. Surprisingly, only one or two delegates appeared from the United Kingdom, Canada and Japan, that were well represented at former meetings.

For the most part, 2 sessions were held in parallel over a period of 7 days with a break in the middle. The topics dealt geneally with the following: numerical methods, asymptotic methods, non-linear and parametric phenomena, waves in random media, electromagnetic fields in plasmas, open and bounded transmission lines, antennas, periodic structures, open resonators, and radio wave propagation. Most of the Soviet papers were presented in Russian with simulatneous translation into English provided. The "foreign" papers were all presented in English with simultaneous translation in Russian also provided. this system worked fairly well in spite of some difficulties with the translation of special technical terms. The slide projection facilities were at least adequate, with no provision for other than 35 mm slides.

The conduct of the sessions was carried out according to those at previous all-Union symposia on diffraction theory, and presumably at other similar Soviet meetings. After presentation of each paper, the Chairman called for specific questions that the author was expected to respond to. Then, the Chairman solicited comments from the floor. These could be devastating in their criticism, and personal feelings were not spared. In one example, the speaker had to withstand a barrage of hese attacks before he was allowed to make any kind of a rebutal.

It is well nigh impossible to give any more than a cursory view of the numerous contributions at this meeting. Here I will select some of the highlights. By definition, these include the 30-minute invited review papers and other contributions assigned 20 minutes or more. They are itemized as follows:"Space-Time Rays in ispersive Media" by L.B. Felsen (USA) (An excellent review of space-time ray concepts as applied to propagation of signals in dispersive media possessing gradual, abrupt, spatial or temporal inhomogeneities);"Stochastic Aspects of Wave Propagation" by J.B. Keller (USA);"Self Consistent Theory of Plasmas" by N. Marcuvitz (USA); Beam Waveguides of Minimum Hardware" by G. Toraldo di Francia (Italy);"Application of R-function heory for the Solution of Boundary Value Problems in Electrodynamics" by V.F. Kravchenkom, V.I. Polevoy and V.L. Rvachyov (USSR) "A Numerical Solution of Some Direct and Inverse Problems of Electrodynamics" by A.N. Tikhonov, V.I. Dmitriev, A.G. Sveghnikov and A.S. Il'insky (USSR);"Geometrical Optics Approximations and Related Asymptotic Methods for Electromagnetic Waves in Inhomogeneous and Nonstationary Dispersive Media" by Yu.A. Kravtsov, N.S. Stepanov and Yu.Ya. Yaschin (USSR);"The Generalized Eigemfunction Method in Diffraction Theory" by N.N. Voytovich, B.Z. Kalzenelenbaum and A.N. Sivov (USSR);"Beam Optics" by G.A. Deschamps (USA);"Stable Numerical Methods to Calculate the (Required) Current Distribution (for) the amplitude Radiation Pattern in Antenna Synthesis" by L.D. Bakhrakh et al. (USSR)

NEWS FROM THE COMMISSIONS

Commission B

Following the tradition within Commission B, Prof. A.D. Olver issued a newsletter, which was also mailed to the URSI Secretariat. A selection has been made out of this Newsletter by the Secretariat, since part of it has already been published either in previous Bulletins, or as part of the Kyoto General Assembly Proceedings.

This is the first Commission B Newsletter of the 1993-96 triennium. I became Chair of Commission B at the General Assembly in Kyoto last September and took over from Professor Fred Gardiol. Fred has done an excellent job as Chair of Commission B from 1990-93. He enhanced the high reputation set by a long line of good Chairs which has helped to make Commission B one of the most active of the URSI Commissions. I was privileged to work with Fred and particularly admire his conscientious and courteous manner of working with people. It is my aim to try to maintain the high standards which my predecessors have set.

The purpose of this newsletter is to keep the Commission B community informed of events, both past and future. Interesting items can be sent to me any time - preferably by e-mail. The newsletter is sent to Official Members of Commission B in each country who are encouraged to copy and distribute as appropriate.

This newsletter reports the technical and business sessions at the Kyoto General Assembly. This may seem a long while ago, but it is worth reporting because the technical sessions were excellent, due mainly to the efforts of the Convenors who hade put together a first-rate combination of invited and contributed papers.

The main Commission B event of this triennium is the St. Petersburg Electromagnetic Theory Symposium. This presents a considerable challenge to organise and is being done jointly by Professor Buldyrev in St.Petersburg any myself. So far things are running smoothly and the Call for Papers is now available. It is printed at the end of the newsletter. I hope you will do everything possible to publicise the Symposium and make it a success. The deadline for the submission of Synopses is 15 September 1994.

Best wishes for a successful 1994

Yours sincerely

David Olver

Venue for the 1998 Electromagnetic Theory Symposium

The Postal Ballot to choose the venue for the 1998 Electromagnetic Theory Symposium resulted in the following votes:

Thessaloniki, Greece 17

Tucson, Arizona, USA 10

Thus the 1998 Symposium will be held in Thessaloniki, Greece and the Local Organising Committee will be chaired by Professor E. Kriezis. The Conference Committee will (as usual) be Chaired by the Chairman of Commission B.

Review of Radio Science Diskette

The 1993 Review of Radio Science (Oxford University Press) has two parts, the book consisting of short reviews and a bibliographic diskette. The bibliographic diskette contains an impressive list of references, occuping 814K bytes originally submitted by the national Commission B representatives. The references are subdivided into eight topic areas and for each area an editor reviewed the material, introduced suitable subdivisions, and suggested additions and deletions. The topic area editors often engaged colleagues in this task. The overall editing was done by Prof Staffan Str!m, assisted by Dr. Jonas Björkberg.

The eight topic areas and the editors are (1) Scattering and diffraction (Prof A.J. Devaney, with the assistance of Dr. A. Schatzberg); (2) Inverse scattering (Same Editors as for (1)); (3) Computational techniques (Prof. Y. Okuno, with the assistance of Drs A. Matsushima, M. Nishimoto and A.Nosich); (4) High frequency techniques (Prof. P. Pathak); (5) Transient fields (Same Editor as for (4)); (6) Guided waves (Prof. M. Salazar-Palma); (7) Antennas (Dr. E. Kuhn, with the assistance of Dr. V. Hombach); (8) Propagation in random, inhomogeneous non-linear and complex media (Prof. N. Engheta).

Any comments on the diskette and would be welcome by Professor Anton Tijhuis who will be compiling the 1996 bibliography (e-mail: a.g.tijhuis.em.ele.tue.nl, fax: +31 40 448375)

Young Scientist Awards for 1995 Electromagnetic Theory Symposium

Commission B has put aside most of its allocation from the URSI Board to support Young Scientist at the St.Petersburg Electromagnetic Theory Symposium. Nomination of Young Scientist (under 35 years of age) are welcome and should be made to the Chair, Professor David Olver.

The Call for Papers for the 1995 Commission B Electromagnetic Theory Symposium is reproduced on the next two pages. Please make the details known to everyone with an interest in electromagnetics, so that we can ensure that the event is a great success.

IV Suzdal URSI Symposium on Artificial Modification of the Ionosphere

15-19 August, 1994, Uppsala, Sweden

The fourth in a series of international URSI (International Union of Radio Science) symposia on Artificial Modification of the Ionosphere, initiated in 1986 with the first symposium at Suzdal, Russia, will be held August 15 through August 19, 1994, in Uppsala, Sweden.

The scientific activities will consist of invited review lectures, invited and regular oral papers, poster papers (including short presentations and special session discussions), and general discussions.

The sessions will cover

- Physics of the processes in the field of interaction of HF radiation with the ionospheric plasma.
- Modelling and influence of the modified ionosphere on radio propagation.
- Geophysical phenomena initiated by active influence of the near-Earth ionosphere and associated ecological aspects.
- The use of the HF modifier as a remote sensor of the upper atmosphere.
- The use of the near-Earth ionosphere as a space plasma laboratory.
- Future HF modification facilities and activities.

The schedule will be according to the following preliminary programme:

Sunday August 14:	12:00-22:00 Check-in, Registration, Get Together Reception
Monday August 15:	09:00-12:00 Opening, Morning session
	13:30-16:30 Afternoon session
Tuesday August 16:	09:00-12:00 Morning session
	13:30-16:30 Afternoon session
	18:00-21:00 Evening Session
Wednesday August 17:	09:00-12:00 Morning session
	13:30-18:00 Excursion and sightseeing
	19:30-24:00 Banquet
Thursday August 18	09:00-12:00 Morning session
	13:30-18:00 Afternoon session
Friday August 19	09:00-12:00 Morning session
	13:30-16:30 Afternoon session
Saturday August 20	09:00-12:00 Closing, Check-out

Full board and lodging (hotel room, breakfast, coffee/tea/snacks, lunch, dinner) will be available at the new and comfortable Hotell Svava, Uppsala, at a discounted price of SEK 800 (approximately USD 100) per person and day (single occupancy) and SEK 200 extra per person and day (accommodation only) for double occupancy and is strongly recommended.

Hotell Svava, with its 80 single and 10 double rooms, is located in the centre of Uppsala, approximately 200 metres from the Uppsala central station with excellent communications to Stockholm by commuter trains (45 minutes) and to Arlanda International Airport by airport coaches (30 minutes). The scientific sessions and meetings will be held at the adjacent modern "Folkets Hus" conference centre. In addition to the Hotel Svava, a limited number of low-cost, self-catering accommodation alternatives will be available. The total number of participants will be limited to 130 persons.

With its 13th century cathedral, one of the world's oldest universities dating back to the 15th century, a 16th century castle and numerous other historical buildings, Uppsala is a very interesting and scenic city and a cultural centre of Sweden. Sightseeing as well as social and accompanying persons programmes will be organized.

The conference fee is USD 200.

* The absolute hard deadline for applications and abstracts is Friday, June 10, 1994!
* E-mail submission of abstracts is preferred.

Special LaTeX macros will be available upon request from Bo Thide' (e-mail bt@irfu.se) who can also provide further information.

Attendance will be granted on a first come/first served basis. Some limited support for travel and accommodation for young scientists and participants from the former Soviet Union will be available.

There will be a special issue of the Journal of Atmospheric and Terrestrial Physics devoted to papers presented at the Symposium.

Organizing committee:
Bo Thide, Chairman
Paul Bernhardt, USA.
G. S. Bochkarev, Russia
Lev M. Erukhimov, Russia
Aleksander V. Gurevich, Russia
Min-Chang Lee, USA
V. V. Migulin, Russia

For further information please contact:

Bo Thide, Chairman

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Fax: +46 18-40 31 00

ANNOUNCEMENTS OF URSI-SPONSORED MEETINGS

Workshop on Low and Equatorial Latitudes in the International Reference Ionosphere (IRI)

9-13 January, 1995, National Physical Laboratory, New Delhi, India

Sponsors (expected): COSPAR, URSI, IAGA, COSTED, CSC, ISF, INSA

Objectives:
This meeting continues the series of annual workshops coordinated by the URSI/COSPAR Working Group on the International Reference Ionosphere (IRI). IRI is the international standard representation of ionospheric densities, temperatures and drifts. The prime objective of the 1995 meeting are potential improvements and extensions of the IRI model at low and equatorial latitudes. Empirical and theoretical contributions are welcome. Of particular interest are: (a) comparative studies of IRI with data, simulations and other models; (b) investigations that could lead to better representation ofionospheric parameters in IRI; (c) regional mapping of E and F peak parameters; (d) occurrence statistics for Spread-F and other ionospheric irregularities; (e) applications of IRI in science, engineering, and education. One workshop day will be dedicated to the Verification of Ionospheric Models (VIM) effort of the URSI Working Group on Ionospheric Informatics (WGII). The Workshop will be part of the Diamond Jubilee celebration of the Indian National Science Academy (INSA) established in 1935. Dr. A. P. Mitra will be the Local Workshop Convener for INSA.

Programme Committee:

D. Anderson	M.A. Abdu	D. Bilitza
A. Danilov	T.L. Gulyaeva	K.K. Mahajan
A.P. Mitra	K. Oyama	K. Rawer

Local Organizing Committee:
A.P. Mitra (Chair)

Please send abstract to:
D. Bilitza, HSTX, NSSDC
7701 Greenbelt Road
Greenbelt, MD 20770, U.S.A.
Fax : +301 441-9486, phone : +301 441-4193
E-mail: BILITZA@NSSDCA.GSFC.NASA.GOV
and NCF::BILITZA

Deadline: August 31, 1994

Accommodation:
Lodging will be provided in the NPL Guest House (single and double bedrooms; cost is about 5 US dollar per bed).

For reservations, please contact:
K.K. Mahajan
National Physical Laboratory
Dr. K.S. Krishnan Road
New Delhi-110012, India
Fax : +91 11-575 2678, Tel. : +91 11-578 8220

Deadline: October 15, 1994

Travel Support:
Limited travel support is expected for participants from post-communist countries and for young scientists. Please send an application detailing cost requirements with your abstract to D. Bilitza.

Ninth International Conference on Antennas and Propagation

4-7 April 1995, Eindhoven, the Netherlands

Papers are now invited for the Ninth International Conference on Antennas and Propagation (ICAP) to be held at the Technical University of Eindhoven, the Netherlands, from 4-7 April 1995. The conference is being organized by the Institution of Electrical Engineers and co-sponsored by the International Union of Radio Science (URSI)

The growing demands for the radio spectrum, generated by the rapid expansion of radio communication, radar and remote sensing systems have provided a stimulating environment for both antenna and electromagnetic wave propagation research. New systems, including the realisation of truly mobile communication networks, will require major advances in these fields.

ICAP'95 will explore the advances and the novel ideas which will form the basis and the limitations of these systems in the next century.

Papers are now requested on Antennas and Propagation topics over the entire radio spectrum.

Anyone wishing to present a paper at the conference should submit a synopsis by 29 July 1994.

For further information please contact:
Louise Bousfield
Conference Services, IEE
Savoy Place
London WC2R 0BL
United Kingdom
Tel : + 44 71 344 5467
Fax: + 44 71 497 3633
e-mail: Conference@IEE.org.UK
Please quote "ICAP'95" in message.

OTHER MEETINGS BROUGHT TO OUR ATTENTION

PIERS 1994 - Progress in Electromagnetics Research Symposium

11-15 July 1994, Hotel Huis ter Duin, Noordwijk, the Netherlands

The European Space Agency (ESA-ESTEC) and the Electromagnetics Academy are organizing PIERS 1994

PIERS 94 offers more than 50 sessions, of which more than half were organized by inviting distinguished specialists to present their most recent work in electromagnetic research. For those who prefer the focused character of a workshop, the sessions have been arranged in homogeneous streams which provide for a thorough treatment of one topic area over the course of several days. Examples are:

- Electromagnetic theory: computational EM, methods and techniques, applications.
- Electromagnetic compatibility: system analysis tools, verification methodology, statistical approaches, biological effects.
- Active remote sensing: radar polarimetry, surface and volume scattering, retrieval algorithms, interferometry.
- Passive remote sensing: new ways in microwave radiometry and inversion
- Wave propagation: theory, modelling, ionosphere, atmosphere, mobile
- Antennas: theory, microstrip, multi-layer, reflector and array antennas, analysis, synthesis and measurements.
- Devices and materials: millimetre, sub-millimetre, and optical devices, composite and chiral media.

Although it is not a tradition of PIERS, this year the participants will receive the full proceedings of the symposium on CD-ROM. The software supplied will allow to search the abstracts for keywords and to print out the papers of interest. In addition, participants will receive the traditional abstract booklet for use during the conference. The full programme is available electronically through World-Wide Web (WWW, see below).

J.A. Kong, PIERS Chairman
M. Le Fevre, PIERS'94 General Chairman
B. Arbesser-Rastburg, PIERS'94 Technical Chairman
(bertram@xe.estec.esa.nl)

For further information please contact:
ESTEC Conference Bureau (ZRC)
Attn: PIERS 94
P.O. Box 299
NL-2200 AG Noordwijk
the Netherlands
Tel: +31-1719-85005
Fax: +31-1719-85658
e-mail: aelferin@vmprofs.estec.esa.nl

2nd International Symposium on Small Satellites Systems and Services

27 June - 1 July 1994, Biarritz, France

Following the success of the first Small Satellites Systems and Services symposium at Archachon, France in June 1992, the French Space Agency (ESA), Ecole Nationale Superieure de l' Aeronautique et de l'Espace (SUP'AERO) and Ecole Superieure de Telecommunication - Site de Toulouse (ENST) are organising a second symposium. It will be held on 27 June to 1 July 1994 in the new Municipal Casino in Biarritz, France.

Aimed at a wide international public (19 countries in 1992), this new symposium will be the opportunity for those with responsibilities in the design and use of public or private systems to meet and converse.

Everything involved in small satellites will be examined:
Mission and System Analysis
Launchers
Telecommunications
Space Sciences
Earth Observations
Satellite Concepts
Economics
Technologies and Subsystems
Ground Systems and Operations
Space Technologies : Education and Training
Space Technologies : Design and Engineering

Working languages : French and English with simultaneous interpreting

For further information:

Secretariat administratif
Europe Organisation
Chantal Tailhades
40 Boulevard des Recollets
BP 4406
31405 Toulouse Cedex
France
Tel : + 33 61 32 66 99
Fax : + 33 61 32 66 00

INTRODUCING FAGS

by Dr. David Pugh, Secretary of the ICSU Federation of Astronomical and Geophysical Data Analysis Services (FAGS)

The earliest scientific measurements were probably of the movements of the sun through the heavens. When wise men among the ancients developed scientific theories to fit the observed facts, they did so to satisfy the practical human demands of adjusting to the seasons. Like today's scientists, they must have understood the basic experimental requirement : good science needs good data. Studies of the Earth, the solar system, and the universe demand data of the highest quality, measured systematically over as long a period as possible.

Although such observations have been made since time immemorial, few records were kept in a systematic way, to allow detailed analysis and the identification of trends and changes. The Federation of Astronomical and Geophysical Analysis Services (FAGS), formed in 1956, is an interdisciplinary ICSU body. FAGS includes ten individual Services each operating under the authority of one or more of the sponsoring ICSU Unions : IAU, IUGG and URSI. Each Service Director is an acknowledged international authority on the phenomena for which the Service is responsible. Each Director is charged not only with receiving data from a world-wide network of cooperating agencies, but also for quality control, dissemination of data and advice to interested scientists, and above all for applying his expertise to the scientific analysis and interpretation of the integrated sets of observations.

Scientific interest in these analyses continues to grow. For example, recent studies of the variations in the rate of rotation of the earth are important in relation to meteorological changes, glacier distribution in polar regions, geomagnetic activity and space navigation. The long-term changes are of special interest, for example in anticipating the effects of climate trends on the global economy, the possibility that slow tectonic movements and tides may play a role in triggering earthquakes, and the coastal impacts of secular changes in sea levels.

FAGS Services give special attention to questions of instrument calibration, resolution and stability. Reliable scientific analyses of small but important long-term geophysical trends is only possible if the methods of making the measurements over decades and centuries have been carefully controlled. No new measuring procedure can be introduced without careful comparison, and checks for compatibility with the older methods. Here the advice and experience of the Service Directors is invaluable as guidance for the network of individual measuring systems which operate at a national level. Each Service works independently, under the general auspices of FAGS, towards the common goal of long-term scientific excellence in data analysis and interpretation of astronomical and geophysical variability. The sponsoring Unions appoint Advisory Boards with strong international membership to guide and assist each Director to achieve these goals.

Although the central coordination of FAGS began under ICSU as recently as 1956, many of the Services have a longer history. Most maintain data which has been collected over decades, and in some cases, centuries. It is appropriate to consider the special activities of each Service in turn.

International Earth Rotation Service (established in 1895) Paris, maintains the terrestrial reference system for both positions and velocities; it also maintains an extra-galactic celestial reference system and determines the earth orientation parameters which connect these systems; it organizes the observational activities necessary to collect appropriate data. the advent of satellite geodetic measurements, such As Very Long Baseline Radio Interferometry, Lunar Laser Ranging, the Global Positioning System and Satellite Laser Ranging, has revolutionised the accuracy of the studies: crustal movements as small as 2 to 5 mm per year are detectable, and changes in the length of the day are monitored to within 0.0002 seconds. The various IERS results contribute in many ways to space research, astronomy and geophysics. For example, data on earth's rotation are interpreted in terms of mantle elasticity, structure and properties of core-mantle boundary, rheology of the core, underground waters, ocean circulation, atmospheric winds and mass distribution.

Quarterly Bulletin on Solar Activity (1928), Japan, publishes a Bulletin, a record of solar activity, which is as final and complete as possible, for studying short- and long-term activities of the sun. These activities include sunspots, synoptic charts of solar magnetic fields, chromospheric eruptions, intensity of the solar wind, and solar radio emissions. More than 70 observatories and institutes contribute observations to these syntheses.

International Service for Geomagnetic Indices (1932), St. Maur, France, collects and publishes data disturbance variations of the geomagnetic field. Disturbances include sudden commencement of magnetic storms, solar flare effects, and pulsation disturbances. Variations in the intensity of the earth's magnetic field are related to the level of solar activity, and the amount of energy coming from the sun into the earth's environment.

Permanent Service for Mean Sea Level (1933), Merseyside, UK, collects and analyses monthly mean sea level data from a global network of tide gauges. These gauges are operated by a wide range of national authorities: hydrographers, surveyors, oceanographic institutions, and individual university departments. PSMSL works to improve the quality of the measurements, and the range of global coverage. There is a shortage of reliable long-term sea level observations in the Antarctic, and from ocean islands. The latter are important to get an even coverage of the measurements ; to increase the data flow, PSMSL has worked with the Intergovernmental Oceanographic Commission of UNESCO to develop GLOSS, an intergovernmental system for measuring sea levels to common high standards. Altimetry has given a new momentum to these analyses, and in future the emphasis will be on developing integrated products for sea level based on both coastal and satellite measurements. In recent years the prospects of global warming, and possible enhanced rates of sea level rise, have made the demands for PSMSL analyses more urgent. Present rates of sea level rise of 0.15 m per century may increase, but there is no evidence for this yet.

Bureau Gravimetrique International (1951), Toulouse, France, collects on a world-wide basis, all gravity measurements and pertinent information about the gravity field of the earth; it compiles and stores the information on a computerised data base in order to redistribute them to a large variety of scientific users. Other data such as mean values of gravity anomalies, geoid heights, and satellite altimetry derived geoid heights are also collected and distributed to scientists world-wide. The BGI also records absolute measurements of gravitational acceleration. One of the applications in which BGI assists is the preparation of geoids for cartographic and hydrographic applications.

International Centre for Earth Tides (1960), Brussels. Ocean tides are easily observed by the casual visitor, but the gravitational attractions of the moon and the sun are also felt by the solid earth. The tidal forces and the earth's responses to these can be calculated and measured to great accuracy. These earth responses relate to the elasticity of the mantle and to the properties of the liquid core. Movement of water due to ocean tides also affects the crustal deformations observed by sensitive gravity metres, tilt metres and strain gauges. When known, global effects are removed from the records, and the residuals are analysed in terms of local phenomena and tectonic features.

International Ursigram and World Day Service (1962), Chatswood, Australia, describes itself as "The World Space Weather Warning Service". It operates through a network of ten Regional Warning Centres, which have responsibility for collecting data in their geographic area and distributing it to users through the other centres. The wide distribution of these centres is typical of many of the FAGS Services: Paris, Prague, Warsaw, Moscow, New Delhi, China, Tokyo, Sydney Australia, Boulder USA and Ottawa. Warnings of disturbances in the solar terrestrial environment are used by radio communicators, surveyors using geophysical techniques, power line and pipe line authorities, operators of satellites, and a host of scientific users. IUWDS also encourages coordinated observations by preparing the International Geophysical Calendar each year ; this lists a series of 'world days' which scientists may use to carry out synchronised experiments.

World Glacier Monitoring Service (1967), Zurich. Increased interest in possible global warming has focused on trends in the extent of glaciers; maps of fluctuations are published at 5-year intervals. A century of systematic observations clearly reveals a general shrinkage of mountain glaciers on a global scale, which provides one of the most reliable pieces of evidence for a secular warming trend. Glacier inventory information provides the basis for identifying global trends, and for isolating locally anomalous behaviour; but interpretation is not straightforward, and standard procedures for monitoring glacier length and volume must be applied.

Sunspot Index Data Centre (1985), Brussels. Since 1981 the SIDC has collected data from some 40 cooperating centres to calculate a provisional sunspot number, but the records go back as far as 1700. Recently the Service has begun separate analyses of activity in the 2 solar hemispheres. On top of the well known 11 year periodicity in sunspot acidity , there are many shorter and longer-term fluctuations. Apart from strong scientific interest, users include space-centres and telecommunication systems. SIDC issues 12 month forecasts, with necessary cautions. The level of sun spot activity will generally decrease through the 11-year cycle until 1997.

Centre de Données Stellaires (1985), Strasbourg, is the world reference data base for the identification of astronomical objects. It collects all of the useful data concerning these objects from observatories around the world, upgrades this information by critical evaluation and comparisons, and distributes the results for further research. CDS has also had a major part to play in most of the major astronomical space missions, by identifying observed sources, and by helping to solve problems of data archiving and access.

Clearly, there is no typical FAGS Service, but as the above summary shows, there is a general theme of attention to coordinated global observing systems of the highest quality; data assimilation; analysis and interpretation of this data using the best scientific expertise; and a commitment to make these results available for other scientists, and for a wide range of other practical applications.

ICSU and the Scientific Unions provide a small sum of money to assist the Services in their central activities, but the main support comes in each case from the national authorities which undertake these responsibilities for the benefits of international science. The Council of FAGS ensures that standards are maintained, and that where possible, links among the Services are developed. Joint meetings of the Services Directors and the FAGS Council are held every four years, to exchange ideas and experience, and occasional cross-Service scientific meetings are organized. In December 1993 the Permanent Service for Mean sea Level celebrated 60 years of operation at a meeting in London to which it invited Directors of several of the other FAGS Services.

The driving force and the vision which established a coordinated system of astronomical and geophysical observations and analysis within ICSU came from scientists, who demanded, and now receive, data of the highest quality to enhance our understanding of the earth on which we live, and of the solar and stellar systems which surround us. The final acknowledgement must go to the generations of anonymous observers without whose patient and exact application of their measuring skills, none of this would have been possible.

LIST OF URSI OFFICIALS

Note : An alphabetical index of names, with addresses and page references, is given on pages 27-44.

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Prof. W. Dieminger (Germany)
Prof. W.E. Gordon (U.S.A.)
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E.1. Spectrum Management and Utilization
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E.2. Non-Gaussian Noise in Communication
Chair : A.D. Spaulding (U.S.A.);
E.3. High Power Electromagnetics
Chair : R.L. Gardner (U.S.A.);
E.4. Terrestrial and Planetary Electromagnetic Noise
Chair : Z. Kawasaki (Japan);
E.5. Interaction with, and Protection of, Complex Electrical Systems
Co-Chairs : C. Baum (U.S.A.), P. Degauque (France) and M. Ianoz (Switzerland);
E.6. Effects of Transients on Equipment
Co-Chairs : V. Scuka (Sweden), and B. Demoulin (France);
E.7. Extra-Terrestrial and Terrestrial Meteorologic-Electric Environment
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Chair : P.J. Wilkinson (Australia)
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G.2. Studies of the Ionosphere Using Beacon Satellites
Chair : R. Leitinger (Austria)
Vice-Chairs : J.A. Klobuchar (U.S.A.), T.R. Tyagi (India);

G.3 Incoherent Scatter
Chair : J.M. Holt (U.S.A.)
Vice-Chair : P.J.S. Williams (UK);

G.4 Ionospheric Informatics
Chair : D. Anderson (U.S.A.)
Vice-Chair : R. Hanbaba (France).

Commission H : Waves in Plasmas

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J.1. Global Very Long Baseline Interferometry (VLBI)
Chair : R.S. Booth (Sweden)

J.2. Large Millimetre/Submillimetre Array
Coordinators : M. Ishiguro (Japan), R.S. Booth (Sweden)

J.3. Large Telescope
Coordinator : R. Braun (Netherlands)

Commission K : Electromagnetics in Biology & Medicine

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Joint Working Groups

AFG.1. Scientific Uses of the Global Positioning System

Coordinator : Dr. P. Høeg (Denmark)

CGH.1. Wave and Turbulence Analysis

Co-Chair for Commission C : will be appointed later
Co-Chair for Commission G : Prof. A.W. Wernik (Poland)
Co-Chair for Commission H : Dr. F. Lefeuvre (France)

EGH.1. EM Effects Associated with Seismic Activity

Co-Chair for Commission E : Prof. T. Yoshino (Japan)
Co-Chair for Commission G : will be appointed later
Co-Chair for Commission H : Mr. M. Parrot (France)

FG.1. Middle Atmosphere

Co-Chair for Comm. F : Prof. C.H. Liu (China, SRS)
Co-Chair for Comm. G : Prof. S. Fukao (Japan)

GH.1. Active Experiments in Plasmas

Co-Chair for Commission G : Dr. Sa. Basu (U.S.A.)
Co-Chair for Commission H : Dr. P. Bernhardt (U.S.A.)

GH.2. Computer Experiments, Simulation and Analysis of Wave Plasma Processes

Co-Chair for Commission G : Dr. H. Thiemann (Germany)
Co-Chair for Commission H : Prof. H. Matsumoto (Japan)

Time Domain Waveform Measurements

Chair : Prof. T.K. Sarkar (U.S.A.)

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URSI/IAGA.1- VLF/ELF Remote Sensing of the Ionospheric and Magnetosphere (VERSIM)

Co-Chair for Commission G : Dr. A.J. Smith (UK)
Co-Chair for Commission H : Dr. U.S. Inan (U.S.A.)

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The object of the International Union of Radio Science (Union Radio-Scientifique Internationale) is to stimulate and to coordinate, on an international basis, studies in the field of radio, telecommunication and electronic sciences and, within these fields:

a) to promote and organize research requiring international cooperation, and the discussion and dissemination of the results of this research ;
b) to encourage the adoption of common methods of measurement, and the intercomparison and standardisation of the measuring instruments used in scientific work ;
c) to stimulate and coordinate studies of :
   - the scientific aspects of telecommunications using electromagnetic waves, guided and unguided.
   - the generation and detection of these waves, and the processing of the signals embedded in them.

The Radioscientist

Vol 5 No 2 June 1993

News, notes and announcements:

Feature Articles:

Reviews:

New Products and Services:

NEWS

New restriction on electromagnetic materials

Akhlesh Lakhtakia (Pennsylvania State University) and Werner Weiglhofer (University of Glasgow) claim to have proven the impossibility of media with certain electromagnetic property: nonreciprocal bi-isotropic materials. They disclosed their proof in Périgueux, France, where the workshop Chiral '94 was held in 18-20 May 1994. This meeting gathered over 90 researchers around the world to discuss electromagnetic effects in complex materials.

It is well known that nonreciprocal materials exist; an example is the antiferromagnetic Chromium Oxide. But there the phenomenon is anisotropic, in other words, the magnetoelectric effect depends on the direction of the field. The core of Lakhtakia's and Weiglhofer's message is that no material can exist where the nonreciprocity effect is isotropic or direction-independent. The proof is based on the covariance behaviour of the medium parameter tensor that contains the polarisation characteristics of matter.

Ari Sihvola

Helsinki University of Technology

A Solar-Radio-Astronomy Meeting in Potsdam

The European Solar Radioastronomers met from May 16-20 in an idyllic place near Potsdam (Germany), called Caputh and widely known as the living place of Albert Einstein during his German years, to discuss recent findings in solar radio astronomy and to plan new directions of research. This years meeting included guests from Japan, the United States, and a considerable number of participants from Russia. Organisation was in the hands of the German Solar Radio Astronomy Group at the newly-founded Astrophysical Institute Potsdam-Babelsberg.

The meeting was very successful giving plenty of time for discussions among the scientists about various fields: theory, observation and the existing or new satellite missions like YOKOH, SOHO, OPEN, WIND, FAST, CLUSTER, CELIAS, and SAMPEX which are partially designed for adding to solar flare, particle, and radiation measurements.

As in all fields of research, theory focussed on simulation work. Part of this effort is devoted to simulation of radio emission during the various solar radio bursts, including particle acceleration, a still barely resolved problem. An interesting simulation model was presented by Loukas Vlahos (Greece) which is based on chaotic distributions of magnetic fields and includes reconnection and acceleration. This model which can be called a Flare Theory of Everything seems to be capable of reproducing the time and space ordering of many solar radio bursts during flares particularly that of radio spikes which seem to provide the elementary building blocks of flares. Highlights of observations included the observation of periodical acceleration in flaring solar loops, periodical injection of electrons into chromosphere and corona, and the observation of higher harmonics in solar radio emissions at gigahertz frequencies. Much interest has been arisen by the excellent observations of the Japanese spacecraft YOKOH providing unprecedented insight into the dynamics of solar flares. Discussion of the prospective new spacecraft missions concentrated on their possibilities for advancing solar radio astronomy. Of particular interest is the observation of the frequency range between 5 MHz and 40 MHz which is possible only from space. However, as has been pointed out, due to space pollution by manmade signals one must go rather far away from Earth to have clear observational conditions. Moreover, particle detection in connection with solar emissions is of interest as is the high energy part of the radiation spectrum which gives information about the injection and acceleration processes.

Altogether the meeting was interesting and successful. It is planned to repeat it next year at another place. Money is available for support of a limited number of students who want to participate. Though the meetings are generally restricted to the European Radio Astronomers, a limited number of external participants will always be invited.

Rudolf Treumann

Max-Planck-Institut für Physik und Astrophysik, Garching, Germany

electronic URSI NEWS to nearly 300 readers

At last tally (mid June) there were 269 individual email addresses for receiving the *electronic URSI NEWS*. This was a jump from 230 at the end of May and was largely due to individual Correspondents discovering our URSI NEWS ad in the March *Radioscientist & Bulletin*. As more receive their March *RS&B* (in remote places like NZ) and get around to reading the issue, this number should have risen considerably by the time you get this June issue of *RS&B*.

The list below shows the number by "country" (not necessarily political entities). There is room for many more readers. Nearly 3000 receive the RS&B, so if a third of these have email access there must be a potential readership of around 1000 for URSI NEWS. Subscription is free — you need only to email "ADD ME" to ursi@physics.otago.ac.nz to be added to the list (see ad elsewhere this issue). There are many more readers in the Former Soviet Union (territory code "su") than addresses since many addresses have multiple readers. The countries or territories in the list below were deduced (or merely guessed in some cases) from the 2-letter code in the Internet address. There is no code for USA (though I once saw "us" being used). Maybe some other countries, and some networks like "bitnet" and "freenet", show no country code and so the number for USA may be overestimated.

ar (Argentina):	3
at (Austria):	1
au (Australia):	15
be (Belgium):	14
bg (Bulgaria):	1
br (Brazil):	1
ca (Canada):	10
ch (Switzerland):	3
cl (Chile):	3
cz (Czech Rep/Slovakia):	3
de (Germany):	10
dk (Denmark):	6
es (Spain):	3
fi (Finland):	8
fr (France):	8
gr (Greece):	2
hu (Hungary):	5
il (Israel):	4
it (Italy):	3
jp (Japan):	15
kr (Korea):	1
my (Malaysia):	2
nl (Netherlands):	6
no (Norway):	4
nz (New Zealand):	8
pl (Poland):	4
se (Sweden):	14
su (Russia and FSU):	19
tr (Turkey):	2
tw (Taiwan):	1
uk (United Kingdom):	16
za (South Africa):	7
[no suffix] (USA):	67

Richard L Dowden

electronic URSI NEWS, ursi@physics.otago.ac.nz

THE EDITOR'S PAGE

Unless we can speed up the printing and delivery process, you won't read this until August. This would be two months late for this "June" issue, but still an improvement on the "March" issue which was over three months late. We will try to get the September issue to you by early September but that means we must get the Radioscientist part to Belgium by mid-July. The fast part of the process is this trip from New Zealand to Belgium — by FTP it takes only an hour or so for the 50 MB file.

The URSI Board of Officers will review these first two issues (March and June) at their annual meeting in August. By the time you read this it may be too late to make comments for this review. However, I will invite comments by email in the electronic URSI NEWS which about 10% of you receive. Maybe this percentage will grow in the next few weeks (I am writing this in early June) as many URSI Correspondents see our advertisement for URSI NEWS in the March RS&B for the first time (the circulation of the RS&B is about four times that of the old *Radioscientist*).

In this issue we continue our series of articles on the early days of "wireless" as it was called then. Curiously, with the advent of cell telephones and computer networks using radio links, "wireless" is back in vogue. Maybe URSI should change back to the name of its forerunner, TSFS (rendering to "Scientific Wireless Telegraphy" in English)! Following the article on Oliver Lodge in the March issue, we have one on the cooperation of Fleming and Marconi. We expect more on the Fleming-Marconi partnership and another on Fessenden in future issues. Research down here in New Zealand shows that our greatest scientist, Ernest Rutherford, was also involved in these earliest times of wireless.

It is our intention to keep the "magazine" nature of the Radioscientist ranging from the historical articles discussed above to relatively "heavy" science articles like the two in this issue by Mahmoud and by Wait, respectively. All of these articles are refereed. In this issue the assistance of the referees is acknowledged at the end of each article. In future issues the individual referees will be named if the individual requests it. This is a practise followed by some scientific journals (e.g. the Journal of Geophysical Research). Such acknowledgment, whether anonymous or not, serves to indicate the refereed articles since news items, "products and services" (a new department beginning in this issue) and book reviews are not peer refereed.

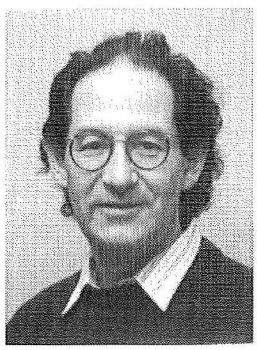
As a peer refereed, international journal, your scientific articles, if accepted and published in the *Radioscientist & Bulletin*, get the same rigorous treatment and exposure to the international community of radio science as they would in other journals. Although the *RS&B* is only a quarterly, the delay from submission to publication may be only 2 – 5 months, depending on submission date. This compares very favourably with some journals with delays of about 12 months.

Since the RS&B has just started, we thought it appropriate you be introduced to the editorial team of the Radioscientist section. I doubt if any of us have met all the others, so we need these bio pics for our editorial staff "meetings" by email. For the foreseeable future we will introduce only additions to the editorial team.

Editor

Richard Dowden was born in Boorowa, NSW, Australia. He received his BSc from the University of Sydney in 1955, but his MSc (1959), PhD (1963) and DSc (1975) are all from the University of Tasmania. Early interests were in radio astronomy, particularly HF radiation from Jupiter. Later he became interested in VLF propagation, amplification and generation in the magnetosphere. Current interest is scattering of VLF waves from precipitation-induced and lightning-induced anomalies in the earth-ionosphere waveguide. He has published ~ 80 papers in these fields. In 1966 he was appointed Professor of Physics (later Beverly Professor) at the University of Otago, NZ, the position he presently holds. He was awarded the Mechaelis Memorial Gold Medal and Prize in 1984 for upper atmosphere research, was elected Fellow of the Institute of Physics (UK) in 1968 and Fellow of the Royal Society of New Zealand in 1983. He has served as NZ National Chairman of the Institute of Physics (1974-75) and as President of the NZ Institute of Physics (1983-84). He was Chairman of URSI Commission H (1984-87) and has served two terms as URSI Vice President (1987-93). He is currently Co-Chair of the URSI Publications Committee, Editor of *the Radioscientist* part of *RS&B* (which he founded in 1990), and Co-editor of the *electronic URSI NEWS* introduced this year.

Associate Editors



Rudolf Treumann was born in Vienna in 1942. Educated in theoretical Physics, Geophysics, and Astrophysics, he graduated as PhD. Rudolf worked as adjunct Professor of Astrophysics at Dartmouth College, Hanover, New Hampshire, and Privatdozent at the University of Munich. He later became Senior Research Scientist at the Max Planck Institut für Physik und Astrophysik, Institut für extraterrestrische Physik. Rudolf's main field of research is the physics of the magnetosphere: plasma wave and nonlinear phenomena in the magnetosphere. He is a member of AGU, IAU, European Astronomical Society, Swiss Astronomical Society, URSI and the editorial board of *J General Evolution*. His publications number more than 100.

INTRODUCING THE EDITORIAL TEAM

D Llanwyn Jones was born in Sutton Coldfield, England on 14th Febrary 1938. He obtained the BSc and PhD degrees from the University of London, King's College in 1960 and 1963 respectively. At King's College, he was appointed to a Lectureship in 1962 and to a Readership, his current post, in 1972. He has led the Radiophysics Group since 1972. He has held visiting professorships in the University of Colorado (1968-1969), the University of Nagoya in 1975 and the University of Kochi in 1987. In Colorado he was one of the first Visiting Fellows of the Cooperative Institute for Research in Environmental Sciences. His research work has been in the theory and observation of the propagation of ELF and VLF radio waves in the Earth-ionosphere duct and in the radio emissions from lightning. The enduring interest has been in experimental and theoretical aspects of the Schumann resonances. More recently, his research has developed in the theory and computation of ionospheric and sub-surface radio waves. He has attended many URSI General Assemblys, several as the UK delegate to Commisions E or G. He is currently the UK representative for Commission E.

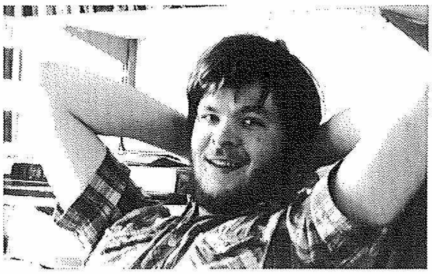
W Ross Stone received his AB in Earth Sciences (Geophysics), and his MS and PhD, both in Applied Physics, from the University of California, San Diego.

Ross has been Editor-in-Chief of the IEEE Antennas and Propagation Magazine (and its predecessor publication) since 1984. He has held positions of Senior Scientist with General Atomic (1969-1973); Senior Scientist with Megatek Corporation (1973-1980); Principal Physicist, Computer Center Director, and Research Adviser with IRT Corporation (1980-1987); corporate Chief Scientist, McDonnell Douglas Technologies (1989-1990); and corporate Chief Scientist, Expersoft Corporation (1990-1992), all in San Diego. He is currently President of Stoneware Ltd (1976-present), through which he holds the position of Executive Director of the Fund for International Scientific Interchange, which offers scholarships in telecommunications to workers in that field. He has authored over 80 journal papers and symposium presentations, and over 80 reports. He has been corporate author of three books, one of which had the largest sales of any IEEE Press book for 1990. He has been a Director of three corporations.

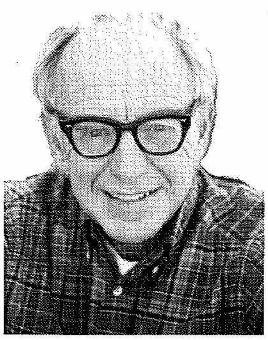
Ross Stone was elected a Fellow of the IEEE "For contributions to the fields of inverse problems and computational electromagnetics." Ross has been Editor-in-Chief of the IEEE Antennas and Propagation Magazine since 1984, and was responsible for its acceptance as a refereed, archival publication of the IEEE. He was Editor-in-Chief of the International Union of Radio Science (URSI) *Review of Radio Science*, 1990-1992, a publication of The Oxford University Press, and is Editor-in-Chief of the *Review of Radio Science*, 1993-1995. He originated the URSI Collected References on Disk, was Associate Editor of the previous *Review*, and has edited several international URSI Commission contributions. He is Co-Chair of the URSI Publications Committee. He was an Associate Editor of the URSI Radioscientist, and is an Associate Editor of the URSI *Radioscientist & Bulletin*. He has served as a member of the URSI Inter-Commission Working Groups on Remote Sensing, on Inverse Scattering, and on the Environmental Effects of EMP. He was the representative of the IEEE Antennas and Propagation Society to the US National Committee of URSI (1984-1992) and as such was an appointed member of the National Research Council of the National Academy of Sciences, and is a member of Commissions A, B, F, and G of USNC/URSI. He is a member of the IEEE Antennas and Propagation, Geoscience and Remote Sensing, Computer, Communications, and Signal Processing Societies. He was elected to membership in the Electromagnetics Academy, and is also a member of the Optical Society of America, the Acoustical Society of America, the Society of Professional Journalists, the Society of Technical Communicators, the Society of Industrial and Applied Mathematics, the Association of Computing Machinery, the Society of Photo-optical Instrumentation Engineers, the Society of Exploration Geophysicists, the National Association of Desktop Publishing, the American Society of Nondestructive Testing, and the Applied Computational Electromagnetics Society.

Robert Hunsucker was born in Portland, Oregon, USA. After graduating BS (1954) and MS (1958) (Oregon State), and PhD (1969) (Colorado), he has spent much of his professional life at the University of Alaska at Fairbanks until 1988 when he left as Professor Emeritus of Physics and Engineering. He has remained at Fairbanks as Senior Partner of RP Consultants. His current research interests are radio wave propagation and radio physics — in particular, backscatter investigations of polar ionospheric phenomena, Alaskan radio communications studies and ionospheric propagation phenomena at high latitudes. He has been active in Commissions G and H of URSI both locally (USA) and internationally in the Working Groups INAG and Incoherent Scatter. As well as some 70 research papers, he published a book, *Radio techniques for probing the terrestrial ionosphere*, in 1991 and has co-authored another scheduled for publication in 1995. He served as Associate Editor of *RADIO SCIENCE* from 1990 to 1992. In addition to scientific works he has published several other articles and poems.

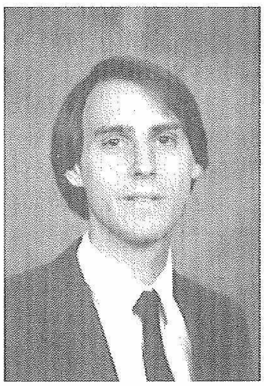
Ari Henrik Sihvola was born on October 6th, 1957, in Valkeala, Finland. He received the degrees of Diploma Engineer in 1981, Licentiate of Technology in 1984, and Doctor of Technology in 1987, all in Electrical Engineering, from the Helsinki University of Technology, Finland. From 1985 to 1986, he was a visiting engineer in the Research Laboratory of Electronics of the Massachusetts Institute of Technology, Cambridge, and in 1990-1991, he worked as a visiting scientist at the Pennsylvania State University, State College. Presently, he is Docent at the Electromagnetics Laboratory of the Helsinki University of Technology with interest in electromagnetic theory, remote sensing, and radar applications. Ari Sihvola is Secretary of the Finnish National Committee of URSI (International Union of Radio Science) and Secretary-Treasurer of the IEEE (Institute of Electrical and Electronics Engineers) MTT/AP Chapter in Finland as a member of the IEEE MTT Society Committee on Eastern Europe and the Former Soviet Union. He also served as the Secretary of the 22nd European Microwave Conference, held in August 1992, in Espoo, Finland. Ari has been an associate editor of *Radioscientist* for several years. He served for four years as Associate Editor for the Finnish electrical and electronics journal *Sähkö-Tele*, also workshop proceedings books mainly the chiral workshops (*Bi-isotropics '93* in Espoo, Finland (February 1993) and *Bianisotropics '93* in Gomel, Belarus (October 1993).



Review Editors



James R Wait received BASc, MASc, and PhD degrees from the University of Toronto. From 1955 to 1980, he was a member of the scientific community in Boulder, Colorado. His positions included Senior Scientist at NOAA, Professor Adjoint in EE at the University of Colorado, Consultant to the Institute for Telecommunications, and Fellow of the Cooperative Institute for Research in Environmental Sciences. In 1980, he became professor of Electrical Engineering and Geosciences at the University of Arizona in Tucson. Jim Wait has received numerous awards for his research in electromagnetics and electrical geophysics, including the Balth van der Pol Gold Medal, presented by URSI in Helsinki in 1978, the IEEE Centennial Medal in 1984, the IEEE Geoscience and Remote Sensing Achievement Award in 1985, the IEEE Antennas and Propagation Distinguished Achievement Award in 1990 and IEEE Hertz Medal 1992. He is a fellow of the IEEE, and is a member of the US National Academy of Engineering. Jim was founding editor of *Radio Science* (1959-1966), Co-editor of *Intl EM Wave Series* (1960-1973). He is co-editor of *IEE* (1974 to date). In 1988, Jim Wait was appointed a Regents Professor at the University of Arizona. In 1989, he retired from the University to become a private consultant.



Steven L Dvorak received the PhD degree in electrical engineering from the University of Colorado, Boulder, in 1989. He is currently an Assistant Professor in the Department of Electrical and Computer Engineering at the University of Arizona. Dr Dvorak previously held a position with TRW Space and Technology Group from 1984 to 1989.

His principal interests include wave propagation, analytical and computational electromagnetics, applied mathematics, and microwave measurements.

Steven is an elected member of the International Union of Radio Science Commission B and a member of the IEEE.

Production Editor

Peter Dowden was born and educated in Dunedin, New Zealand. Following a year as a railway shipping clerk, he had three entertaining years studying economics at the University of Otago. Since then Peter worked variously as a busker, truckdriver, school lab assistant, research assistant, taxidriver and tram conductor. He has been a member of several choirs and orchestras, and is currently a member of Otago University Yacht Club and a literary appreciation group, The Arthur Ransome Society, for which he edits an electronic journal *Signalling to Mars*. Peter is currently occupied by schoolbus driving, publishing work for URSI, and research and publicity for University of Otago.

Production of *the Radioscientist* is also assisted by **Helen Wreford** of the Otago Physics Department.

Fleming and Marconi: The Cooperation of the Century

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Electromagnetic Systems Branch, NASA Johnson Space Center, Houston, Texas, USA.

Abstract

Professor John Ambrose Fleming serving as the Scientific Adviser to Marconi's Wireless Telegraph Co Ltd was entrusted by Guglielmo Marconi to help design the Poldhu transmitting system that sent wireless signals across the Atlantic Ocean on 12th December 1901 and revolutionised the world of communications. A student of James Clerk Maxwell at Cambridge, Fleming was the scientific and technical link between Clerk Maxwell and Marconi. The intimate professional interaction between these two pioneers during the planning, design and execution of this epoch-making experiment remains poignantly captured in many letters of correspondence between them. This article looks into this correspondence for the first time to examine and characterise this relationship and answer many historic curiosities.

1. Introduction

On 20th July 1897 Guglielmo Marconi created [1] his private Wireless Telegraph and Signal Company to develop commercially his invention in long distance wireless communication. Thus began the revolutionary new era in radio communication at the turn of the century. To assist him with theoretical, analytical and design expertise, Marconi appointed Professor John Ambrose Fleming as the Scientific Adviser to his company. A student of James Clerk Maxwell, Fleming was already an established expert in the electrical power engineering field with keen interest in wireless signalling. In the autumn of 1900 when Marconi decided to embark upon the transatlantic wireless signalling venture, he sought Fleming's assistance in the design of the high power transmitting system to be erected at Poldhu, Cornwall, England.

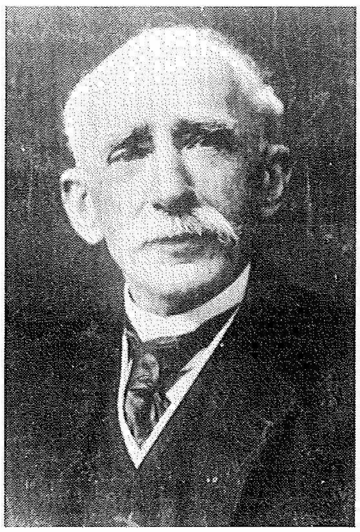
Marconi was particularly entrepreneurial in his experiments with wireless waves. Then just 26 years of age, he kept the preparations for the daring transatlantic wireless venture in great secrecy. At that time it had been experimentally shown in laboratory experiments that electromagnetic waves (then "Hertzian waves"), like light waves, travel in straight lines. Thus the curvature of the earth appeared to be an impediment to transatlantic wireless signalling.

Against this background, there remain many historical curiosities that need to be explored. What was Fleming's view regarding the wireless waves crossing the atlantic ocean when he was assisting Marconi in the construction of the Poldhu transmitting station? Before the actual experiment, did Fleming know that the Poldhu transmitting station being built was actually for the transatlantic experiment and not just a high-power station for communication with the ships on the high sea? With the success of the transatlantic wireless experiment would come the immense prestige and lasting fame in the scientific world. The transmitting system is the key to that success. How did Marconi arrange the involvement of Ambrose Fleming in this regard? If Oliver Heaviside and Prof Kennelly came up with the explanation of transatlantic wireless transmission by means of ionospheric reflections, what was Fleming, the student of Clerk Maxwell thinking at that time? Marconi did not have formal academic credentials when he was presenting his revolutionary results of wireless communication experiments and consequently faced hostile scrutiny from some members of the British scientific establishment. How did Fleming's association with Marconi as the Scientific Adviser appear under those circumstances ?

These historic curiosities are addressed here based on the information contained in the numerous letters between Fleming and Marconi and his company officials. To set the stage for evaluating these intimate technical and personal interactions it is first necessary to provide the backgrounds of these two pioneers.

2. John Ambrose Fleming

One of the titans of 19th and 20th century electrical engineering, John Ambrose Fleming helped usher in the electronic age with his revolutionary invention of the thermionic valve that goes by his name. Fleming was born on 29th November, 1849.



At 14, Fleming went to the University College School, London. After passing the Matriculation exam he entered the College to prepare for a Bachelor of Science (BSc) degree. A brilliant student ever in pursuit of excellence, Fleming's education was interrupted by adverse financial circumstances. After passing Part I of the BSc examination, Fleming took up a job in a firm of shipbuilders near Dublin, Ireland. Upon finding that the work he was set to do was merely copying plans of ships in the drawing office with no opportunity of learning practical engineering, Fleming left the job after 3-4 months and joined the London Stock Exchange as a clerk. This job was to last about two years and as Fleming recalls "By very hard work however, in early morning and in evenings at home, I acquired the requisite amount of knowledge for the final BSc examination and sat for it in the autumn of 1870. I and another candidate were the only names placed in first class."[2]

In January 1871, on the recommendation of Dr E Frankland, a Professor in the Royal College of Chemistry, Fleming began his new employment as Science Master in Rossall School at a salary of £140 per year. But after staying at the school for over a year and a half, Fleming felt that he needed more training in advanced scientific work. So he came back home to London and joined Dr Frankland's laboratory at the Royal College of Chemistry where Oliver J Lodge was a fellow student. He read his first paper on the theory of Volta's Pile on March 21, 1874 at the first meeting of the Physical Society of London (which he helped to found). During 1874 Fleming became a Lecture Assistant to Frankland in the Advanced Chemical Laboratories. (It may be mentioned here that Guglielmo Marconi was born this same year on the 25th of April in Bologna, Italy.) At the end of that session in June 1874, as Fleming recalls, "it became necessary for me once more to take up some remunerative teaching position, in which I could support myself and relieve my parents". [2] So he accepted the appointment of Science teacher in the Military and Civil Department at Cheltenham College in autumn 1874.

2.1 Fleming and Clerk Maxwell

The University of Cambridge on 8th March 1871 appointed James Clerk Maxwell (born 13th June 1831) as the first Cavendish Professor of Physics, to begin cultivation of Electricity and Magnetism, the branch of Physical Sciences where great advances had been made recently. Fleming, ever in pursuit of excellence, longed to go to Cambridge and study under Clerk Maxwell. As Fleming recalled in 1934:

> During my time at Cheltenham College I had been attempting to follow the work of one of the greatest of the nineteenth-century physicists, namely, Professor James Clerk Maxwell. He had published, in 1873,[*] his great treatise on Electricity and Magnetism, in which he had applied his brilliant mathematical powers to translate Faraday's electrical ideas into mathematical language; and the attempt to read Clerk Maxwell's books and papers had brought home to me my own defective mathematical training.
> I therefore desired to go to Cambridge and work under Clerk Maxwell, who had not long before been appointed there as the Cavendish Professor of Physics. My parents and friends thought me very foolish to surrender my good appointment at Cheltenham, where I had an income of £400 per annum, but I knew well it was a blind-alley occupation, and that it was useless to stay on. I aspired to better things than an assistant mastership in a public school.
> As neither my father nor any relatives could assist me financially, I had first to consider ways and means before I could surrender my position at Cheltenham College. First, I determined to endeavour to gain some scholarship or exhibition at Cambridge, and I therefore entered myself as a candidate for an open-entrance Science Exhibition or scholarship at St John's College of 50 pounds for three years. I went up to Cambridge at Easter 1877, and sat for this Exhibition.
> My training in Chemistry and Physics at the Royal College of Chemistry stood me in good stead, and I was successful in winning this scholarship against all competitors. I had also saved about £400 and my good friend Professor Guthrie promised me the assistance of an Examinership to the Science and Arts Department which would secure another £50 per annum. Thus provided, I burnt my boats and severed my connection with Cheltenham College as Science Master in July 1877. [2]

*[*Clerk Maxwell published his theories in a series of papers between 1861 and 1865. These were reprinted in his 1873 book.]*

Fleming attended Clerk Maxwell's lectures, on occasions as the only audience, and worked in the Cavendish laboratory under him on electrical resistance standards, in 1878 and 1879, the last two years of Clerk Maxwell's life.

In the summer of 1879 Fleming took the degree of Doctor of Science in the University of London, the subject being 'Electricity treated Experimentally'. Clerk Maxwell died of abdominal cancer on 5th November 1879 in Cambridge and Fleming's father died five days later. As the eldest son, Fleming had to attend family affairs. Fleming joined the newly formed Edison Telephone Company in London as a Scientific Adviser the same month. He sat for the Natural Science Tripos in the summer of 1880 and obtained the BA degree of the Cambridge University with first class honours in Chemistry and Physics and became lecturer in applied mechanics in the new University Engineering Laboratories. He was made a fellow of St John's in 1882.

2.2. Beyond Cambridge Years

Fleming left Cambridge to become the first Professor of Mathematics and Physics in the University College of Nottingham in July 1881. He stayed there for only about six months and came back to London to join the Edison Electric Light Company as its Electrician in the beginning of 1882 advising on the equipping of generating stations and distribution networks. In 1883 the Edison Electric Light Company and the Swan Electric Light Company amalgamated into one company, and he became adviser to the Edison and Swan combination, particularly on the photometry of lamps. In July 1884 Fleming, on a leave of absence, visited the United States to see progress of Electric Lighting there. But Fleming's "tastes and predilections were for teaching and scientific research work"; so soon after his return from the United States he received the offer from the University College, London to become the first Professor of Electrical Engineering in 1885.

Fleming served as the Scientific Adviser to the London Electric Supply Corporation when it was installing the Ferranti alternating current system in London. He also served as consultant to the London Electric Company and the Town Councils of Peterborough, Plymouth and Douglas, Isle of Man advising on the electrification of these towns. In 1892 Fleming became a Fellow of the Royal Society.

3. Guglielmo Marconi

Guglielmo Marconi, the father of long-distance radio communication, was born at 9:15 AM on Saturday 25th April 1874 in Bologna, Italy. At a very early age he showed keen interest in experiments with electricity and was experimenting with wireless waves in the top floor of his family home at Villa Griffone in Pontecchio near Bologna.

Upon accepting the Nobel Prize in Physics for the year 1909, Marconi in his Nobel Lecture [3] before the Royal Academy of Science at Stockholm, describes his early years in the following manner:

> In sketching the history of my association with Radiotelegraphy, I might mention that I never studied Physics or Electrotechnics in the regular manner, although as a boy I was deeply interested in those subjects.
> I did, however, attend one course of lectures on Physics under the late Professor Rosa at Livorno, and I was, I think I might say, fairly well acquainted with the publications of that time dealing with scientific subjects including the works of Hertz, Branly, and Righi.
> At my home near Bologna, in Italy, I commenced early in 1895 to carry out tests and experiments with the object of determining whether it would be possible by means of Hertzian Waves to transmit to a distance telegraphic signs and symbols without the aid of connecting wires.
> After a few preliminary experiments with Hertzian Waves I became very soon convinced that if these waves or similar waves could be reliably transmitted and received over considerable distances a new system of communication would become available possessing enormous advantages over flashlights and optical methods, which are so much dependent for their success on the clearness of the atmosphere.

While continuously working on his wireless signalling apparatus, Marconi made a fundamental discovery. In his own words:

> In August 1895 I discovered a new arrangement which not only greatly increased the distance over which I could communicate, but also seemed to make the transmission independent from the effects of intervening obstacles.
> This arrangement consisted in connecting one terminal of the Hertzian oscillator or spark-producer to earth and the other terminal to a wire or capacity area placed at a height above the ground, and in also connecting at the receiving end one terminal of the coherer to earth and the other to an elevated conductor.
> I then began to examine the relation between the distance at which the transmitter could affect the receiver and the elevation of the capacity areas above the earth, and I very soon definitely ascertained that the higher the wires or capacity areas, the greater the distance over which it was possible to telegraph. [3]

This is Marconi's first of the three fundamental discoveries [*] [4] in electromagnetic wave propagation that revolutionised the world of communications in the twentieth century.

[The second discovery was the 32 m 'daylight wave' which inaugurated the shortwave era in long-distance radio [8,9] and the third was his discovery of over-the-horizon propagation of quasi-optical 'micro-waves', by tropospheric means [10], advancing the field of communications post-WW2.]*

4. Marconi in England

Marconi's mother, Annie Jameson Marconi of the well-known whisky-manufacturing family of Ireland, was first to recognise quickly the genius in her son and made every effort to advance his invention [5]. After Marconi was unsuccessful in getting the Italian Minister of Post and Telegraph interested in his invention his mother, realising the great potential of his wireless invention in ship-to-shore communications, soon arranged to bring Marconi to England, the greatest maritime nation of the world in the heyday of the British Empire [5].

On 2nd June 1896 Marconi filed for the world's first patent (No 12 039) for wireless telegraphy (Radiation Wireless). The complete specifications for it were filed on 2nd March 1897. It is the American version of this fundamental patent (US patent no 586 193) that placed Marconi in the United States National Inventors' Hall of Fame. [6]

Henry Jameson Davis, Marconi's maternal cousin, arranged for an introductory letter by Mr A Cambell Swinton to the Chief Engineer of the General Post Office, Mr William Preece. Very soon Marconi's demonstrations on his invention began in England. Marconi recalls:

> These experiments were continued in England, where in September 1896 a distance of $1^3/_4$ miles was obtained in tests carried out for the British Government at Salisbury. The distance of communication was extended to 4 miles in March

1897, and in May of the same year to 9 miles. [3]

In August 1898 Marconi impressed an anxious Queen Victoria by sending her wireless medical bulletins on her son the Prince of Wales (later King Edward VII) recovering from an injury aboard the Royal Yacht Osborne at a distance of two miles at sea, separated by intervening hills.

To further develop and commercialise his invention, Marconi formed the Wireless Telegraph and Signal Company on 20th July 1897 with a capital of £100,000. The initial investments came from the family, the Davis and Jameson branches and their friends the Saunders and Ballentynes. Outside money came later [5]. Marconi received £15,000 for his patents from which the official expenses for the formation of the Company were paid. In addition, Marconi received 60,000 of the 100,000 one-pound shares. The remaining 40,000 shares were put on the market for subscription. £25,000 was provided as the working capital.

Further inventions, improvements and experiments in wireless signalling continued at a rapid pace and Marconi observes:

> After numerous tests and demonstrations in Italy and in England over distances varying up to 40 miles, communication was established for the first time across the English Channel between England and France in March 1899. [3]

The stage is now set for the bold venture of signalling across the Atlantic.

5. Fleming's interest in Marconi's early experiments

Fleming, writing (in 1934) as a veteran Professor of Electrical Engineering recalls his observations of Marconi's early wireless works in England:

> My most important piece of consulting work was my connection with Marconi's Wireless Telegraph Company, which began in the autumn of 1899.
> As a pupil of Clerk Maxwell I had for long taken an intense interest in his theory of electromagnetic waves, and in the experimental proof given by Hertz in Germany in 1887 of the existence of these waves and their production by very rapid alternating electric currents. I had also followed very closely the important researches of Sir Oliver Lodge on the same subject, and had myself made apparatus for repeating Hertz's notable experiments.
> Hence when, in 1896 or 1897, it began to be known that a young Italian Inventor had succeeded in using electro-magnetic waves to operate telegraphic apparatus over distances of several miles without the use of connecting wires, and so invented a practical system of wireless telegraphy, my interest in the matter was enormously increased. [2]

Fleming first saw the demonstration of Marconi's spectacular wireless experiments in England in April 1898. He recalls:

> I had the pleasure of seeing it for the first time in April 1898. Mr Marconi had established in the Isle of Wight, at Alumn Bay, and another at Bournemouth, near the Pier. Happening to be at the latter place for a short holiday, I made a request of Mr Marconi to be allowed to inspect it, and he very kindly gave me permission.
> I do not even now forget my astonishment when I saw a telegraphic instrument begin to print down in the Morse Code of dot and dash the message "Compliments to Professor Fleming," which had found its way across twelve miles of sea and been picked up by an aerial wire 150 feet high attached to a mast in the garden of the house in which Mr Marconi was then residing at Bournemouth.
> On April 3, 1899, I wrote a long letter to The Times, describing the results of my inspection and foretelling a great future for this new method of intercommunication. [2]

6. Fleming's appointment as the scientific adviser

The following sequence of letters describe the beginnings of Fleming's long association with Marconi's Wireless Telegraph Company.

[Fleming to H Jameson Davis at the Marconi company]

> May 2nd 1899
> Dear Mr Davis,
> In reference to our conversations and to your kindly expressed wish that I should join you in assisting the Wireless Telegraph Company in some such capacity as Scientific Adviser I have considered the matter and subject to certain conditions I shall be willing to unite with you.
> I should like however to define first my position and views a little carefully. I have a strong conviction of the commercial possibilities of Mr Marconi's inventions apart from their Scientific interest provided they are properly handled. I should desire to see a genuine business of a solid character built up and I should not be in sympathy with the views of any who might desire to exploit the invention merely for financial purposes. Subject however to finding my opinions on this point in agreement with those of your Board generally as I know they are with your own and Mr Marconi's I may then say that I consider the position of adviser to a Company such as yours a position of trust. I do not think that one so placed should make use of information leading to suggestions or inventions to take out patents on his own behalf and then market them with his employers! All that a scientific adviser does in the way of invention, suggestion or advice should be the sole property of those retaining him as far as their own affairs are concerned. I have noticed that any other course invariably leads sooner or later to difficulties and perhaps disputes.
> Hence in fixing my terms I do so on the assumption that you would possess in return my thoughts and any inventions or suggestions I may make in your business as your exclusive property. I should ask a fee of £300 per annum, an engagement for one year certain and renewable year-by-year, the agreement being terminable by either side by three months notice before the expiration of the current year.
> These are the sort of terms I have had as adviser to the London Electric Supply Corporation for five years and with the Edison and Swan Electric Lighting Company for sixteen years.

As regards the time I could give to your affairs, whilst it is not possible for me to promise you an exclusive attention I can always arrange that you shall come to me for assistance whenever you like. No doubt sometimes it will be more than at others. I have had considerable experience in the last eighteen years in dealing with scientific patents and with the sort of difficulties which arise in connection with the establishment of new electrical enterprises so that I hope it may be possible for me to render to your Board substantial assistance, as I have mentioned I have already been turning my attention to the question of erecting safely very high masts or signal towers. If your Board accept my terms I should desire them to understand that my remaining in connection with them would depend essentially upon my approval of the general policy adopted as to the scope and aim of the Company's operations.
Subject to being satisfied on this point I would do my best to advise them and assist in building up a business which shall be on a sound basis. One of the first questions I should desire to see examined most carefully would be the policy and position of your Company in regard to the Post Office Telegraph Department. As regards time of joining you there is nothing to prevent the connection between us being established at once. [...] [*]
J A Fleming

[Here and in all the letters, the concluding pleasantries are deleted.]*

[Davis to Fleming]

9th May 1899
Dear Dr Fleming,
I have pleasure in informing you that at to-day's Board Meeting you were unanimously elected as Scientific Adviser to this Company. Consequently I telegraphed to you to-day as enclosed confirmation but suppose you did not get this in time to come round this afternoon. We shall be glad to see you to-morrow at 11 or as soon after as you can make it convenient to call. Mr Marconi is here and would like to consult you on a little matter of business relative to the subject contained in your note to me of the 5th inst. [...]
H Jameson Davis, Managing Director.

7. The appointment in historical perspective

In defining the terms of his appointment as the Scientific Adviser to Marconi's Wireless Telegraph and Signal Company, Fleming is particular about his strong advice that the Company clearly stay out of the grips of the General Post Office. This advice is based on Fleming's first hand experience with the Government involvement with a new communication enterprise emerging out of the invention of the telephone by Alexander Graham Bell in 1876.

The invention of the electromagnetic telephone, a good receiver, by Bell and the subsequent invention of the carbon button telephone, a good transmitter, by Thomas A Edison brought into existence the formations of two private telephone companies in England — respectively of Bell and Edison, and Fleming was appointed to act as a Scientific Adviser to the Edison Telephone Company in November 1879.

The electric telegraph came into practical existence in Britain around the time when Queen Victoria came to the throne and was nationalised by the government through Acts of Parliament in 1868 and 1869 to abolish monopolies making private profits. The whole business of electric telegraphy was placed in the hands of the General Post Office.

As Fleming recalls [2]:

The Wireless Telegraph and Signal Company, Ltd.
Telegraphic Address, EXPANSE, LONDON.
Telephone No 2748, Avenue.

28, Mark Lane,
London, 9th May 1899
E.C.

Dr. Fleming F.R.So

University College,

Gower street

Dear Dr. Fleming

I have pleasure in informing you that at to-day's Board Meeting you were unanimously elected as scientific adviser to this Company. Consequently I telegraphed to you to-day as enclosed confirmation.

> In order to protect themselves from possible rivalry, these Acts were so skilfully worded that they rendered it illegal to conduct any mode of intercommunication by electricity for public service for consideration or payment.
> When the telephone was first invented, one of the technical officials of the General Post Office had declared it to be a toy and of no use but when the first attempt was made to establish a telephone exchange, the General Post Office took alarm lest the new mode of communication should interfere with their telegraphic receipts. Hence, in 1879 they flung a bombshell into the telephonic camp by declaring that a telephonic line was a telegraphic line within the meaning of the Acts of 1868 and 1869.

Accordingly, they gave notice to the telephone companies of this decision and an important legal action was tried in 1880, under the title of "The Attorney-General v The Edison Telephone Company of London, Limited". Fleming represented the Company along with a group of eminent scientists of the day — Lord Rayleigh, Lord Kelvin (then Sir William Thomson), Professor Tyndall, Sir George Gabriel Stokes etc. But the judges gave the decision in favour of the Crown in spite of the arguments advanced by the distinguished counsel that the telephone is a distinctly new method of electrical communication not even conceived when the telegraph industry was nationalised by the Government. The case was never appealed further. The Bell and Edison telephone companies in Great Britain united into one company and appeared as the United Telephone Company, later the National Telephone Company. Fleming, who served as the Scientific Adviser to the Edison Telephone Company, bitterly observed:

> Thus in consequence of the Acts of 1868 and 1869, the control of this new and wonderful industry of telephony passed into the hands of the General Post Office and its development was thereby retarded in Great Britain in contrast with that in the United States where it was not under government control. [2]

So when Fleming saw a revolutionary new technology of signalling, the Radiation Wireless of Marconi, rapidly emerging, he very much wanted it to be in private hands and to be actively involved in it.

8. The beginning of the trans-Atlantic venture

When did the actual work of Marconi's transatlantic signalling venture begin? Marconi in his Nobel Lecture[3] says

> The belief that the curvature of the earth would not stop the propagation of the waves, and the success obtained by syntonic methods in preventing mutual interference, led me in 1900 to decide to attempt the experiment of testing whether or not it would be possible to detect electric waves over a distance of 4000 kilometres, which, if successful, would immediately prove the possibility of telegraphing without wires between Europe and America. [3]

Fleming (in 1934) recalling his work as Scientific Adviser to Marconi from May 1899:

> When Mr Marconi returned from the United States in the autumn of that year, having demonstrated the possibility of his electric wave telegraphy over a distance of upwards of one hundred miles, he had fully made up his mind to attempt the great feat of bridging the Atlantic Ocean.
> Accordingly, the Company formed to operate Mr Marconi's inventions appointed me in the autumn of 1899 as their Scientific Adviser, and I was asked to consider the specification of the necessary machinery for attempting transatlantic wireless Telegraphy. [2]

But as we see here, Fleming was actually appointed in May 1899, a few months earlier than the 'autumn of 1899' and it is clear that his appointment was specifically for the transatlantic venture. Degna Marconi, Guglielmo's eldest daughter, in her book [5] writes,

> In July of 1900 Major Flood Page and R N Vyvyan had gone with my father by train to Cornwall and decided on Poldhu (pronounced Pol-ju) near the small town of Mullion at the south-west tip of England. To John Ambrose Fleming of the University of London, recently appointed Scientific Adviser to the Marconi Company, went the job of designing the installation. Vyvyan,the red-tape breaker who was also a crack engineer, was in charge of construction, which began in October.

The design work on the transatlantic signalling project [2,7] started increasing tremendously and soon began to bear heavily upon Fleming's time and energy. A breaking point came on 22nd November 1900 when R N Vyvyan, the Engineer in charge of the construction of the transmitting station at Poldhu sent a long letter with technical questions to Fleming. Fleming in a disturbed mind, composed a letter to Major Flood Page, the Marconi company's Managing Director, the following day:

[Fleming to Major Flood Page; first draft: 23 Nov 1900]

> ...I am sorry to trouble you again with my private affairs but I must make reference to the extreme demands on my time which the Wireless Telegraph Company is making. You are probably hardly aware what time is occupied in making replies to enquiries or letters which it takes the questioner but a few moments to dictate.
> I have literally not done a thing this week (except gave one college lecture and reply to one or two little letters) other than wireless answers. Tuesday after dictating letters I had four hours with appointments with Messrs Moulton and [...] [*]. Wednesday 5 hours research at Patent Office and an hour of interview with Pochin. Yesterday all day in the memorandum for Belts and interviews about transformers with manufacturers. Today a long letter from Vyvyan which will take several hours to answer.
> I am feeling that it is not at all reasonable that a general agreement to advise the Company should be interpreted to mean the entire occupation of my time. I can attend to no other work or push forward other consulting business. Added to this I have all the responsibility of invention and design for the

Cornwall plant. A novel dangerous experiment needing every possible precaution and thought if it is not to result in disaster. My present agreement is terminable by three months notice on either side. The Company are taking from me the ripe experience of a life-time of work at present and my remuneration is in no way adequate to the demands. I am willing to do the work on a scale of payments proportional to the responsibility. You are engaged on a gigantic experiment at Cornwall which if successful revolutionizes ocean telegraphy.

My view of the case is that if the work asked of me is to continue at the present amount my salary should be raised to 500 pounds per annum at once as was the case when I was fully occupied for the London Electric Supply Company, and in place of a mere three months engagement I ought to have some prospect of reasonable reward by an increase, if my work and inventions are of material assistance in getting across the Atlantic. I am at present not in a contented frame of mind. ...

[this name in the draft is illegible]*

Fleming redrafted the letter and sent it to Major Flood Page, his old friend, at his house as a semi-private correspondence. Fleming himself defined his new terms and conditions.

[Fleming to Major Flood Page; second version]

My Dear Major,

I send this to your house because I don't want it to be considered official but only as a letter to an old friend. I do not think you have any conception of the extent to which the Wireless Telegraph Company at the present moment is taking my time and thoughts and the services of my assistants. When I first made my agreement with them to advise them generally for £300 a year the arrangement was interpreted very much as I intended it, but in the last six months the work thrown on me has grown to such proportions that all my other consulting work and college teaching is suffering neglect simply because I am overwhelmed all day long with things to attend to for wireless. Everyone in the Company seems to consider that they are to have access to me at all times for as much advice reports or experiments as they please. Hardly a day passes without 2 or 3 letters and everything, from reporting-in patents to writing Admiralty instructions for working an induction coil to testing coherers or measuring Leyden jars for the machine, is sent to me. This is not by any means the whole of it. You would hardly believe it the amount of thought this Cornwall experiment is requiring. As I said the other day we are engaged in a gigantic experiment. It is no routine work like putting up an Electric Light Station.

I have to make every step as far as possible sure by laboratory experiments and continual thought by day and night to give it the smallest chance of success. I shall have without doubt to go down to Cornwall in January perhaps for 10 days or more to conduct experiments with a high tension plant of an exceedingly dangerous character where a moment's carelessness might be fatal to me or someone else.

I am being asked to do all that for what practically amounts, after deduction for my office expenses to about £250 per annum with engagements to hand over to the Company patents for any inventions I make.

The question has been weighing on my mind lately whether at this time of life in spite of the intense fascination of the work I have any right in the interests of myself and those dependent on me to give away practically the whole of my time and energy in any such terms. I know you have had in your mind a revision of them in a sense which will bring them much more into accord with the work.

I know that Mr Marconi will be with you on anything but I want matters brought to a decision before I go down to Cornwall at Christmas

As the following correspondence shows, Marconi and other Company officials consulted and immediately agreed to the salary increase and the three year term of appointment. But immense fame, prestige and business opportunities were associated with the success of the transatlantic experiment. Marconi at 26 was very much in charge of the situation and through the Managing Director spelled out very clearly to Fleming: "...if we get across the Atlantic, the main credit will be and must forever be Mr Marconi's." The Professor and gentleman Fleming, very happy with the raise in his consulting salary and the three-year continuing term of appointment, agrees to that proposition in his letter of the 3rd December 1900.

MARCONI'S WIRELESS TELEGRAPH
COMPANY LTD
TELEGRAPHIC ADDRESS,
EXPANSE, LONDON.
TELEPHONE Nº 2748, AVENUE.
A.B.C. CODE USED.

The agreement was then promptly confirmed by Flood Page on the 6th December 1900.

[Flood Page to Fleming; 'private' note]

27th Nov 1900

My dear Fleming,

Marconi and I agree absolutely with you as to the necessity of giving you higher remuneration than you now have: specially considering the very much larger amount of work you now do, than was contemplated. We have only waited for a Board meeting, as we have not the power (though we have the will) to increase your remuneration as you so naturally desire. This shall be brought before the next meeting. The Board does not meet very often. I am rather tired, down on Friday, up on Monday, without much rest on Sunday. I wrote you a few words from Poldhu yesterday. [...]

S Flood Page

[Flood Page to Fleming]

1st December 1900

Dear Dr Fleming,

It affords me very great pleasure to inform you that the Board to-day cordially approved of your salary being raised from £300 a year to £500 a year.

They quite share your feeling that a three months' engagement is very short, and they are prepared to enter into an engagement with you at the rate of £500 a year for three years.

I am desired to say, that while they recognize fully the great assistance you have given to Mr Marconi with reference to the Cornwall station, yet they cannot help feeling that if we get across the Atlantic, the main credit will be and must forever be Mr Marconi's. As to any recognition in the future in the event of our getting successfully across the Atlantic, I do not think you will have cause to regret it, if you leave yourself in the hands of the Directors.
Trusting that their cordial acceptance of your suggestion as to the salary will meet with like hearty reception on your part and that we may work to-gether for many years to come, [...]
MARCONI'S WIRELESS TELEGRAPH Co. LTD.,
S. Flood Page
Managing Director

[Fleming to Flood Page]

Dec 3rd 1900
Dear Major Flood Page,
I am very much obliged to you for your kind letter received this morning informing me that your Board have cordially approved of my salary being raised to £500 per annum and that they are prepared to enter into an engagement with me for three years on the above terms. I accept with pleasure both these proposals. I desire to add that no effort on my part shall be wanting to promote the interests of the Company and render the Board loyal and, I hope, effective service. As regards any special recognition in the event of my services assisting in the accomplishment of transatlantic wireless telegraphy I can confidently leave this to be considered when the time arrives, assured that I shall meet with generous treatment. I need hardly say that I have no desire now or at any time to claim an atom of credit which can not be fairly accorded to me. Heartily re-echoing your wish that we may have many years yet of successful work together and with kindest regards, [...]
J A Fleming

[Flood Page to Fleming]

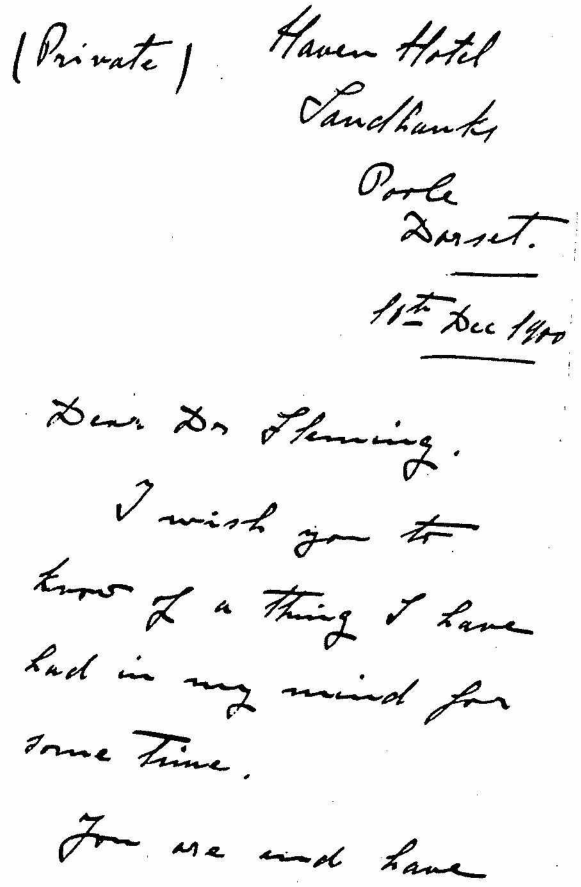
6th December 1900
Dear Dr. Fleming,
I beg to acknowledge receipt of your letter of the 3rd December, in which you inform me that you accept a three year's engagement with the Company, your salary being at the rate of 500 pounds per annum.
It is a matter of great satisfaction to me, and I am sure it will be to my colleagues, to know that we shall have the benefit of your experience and advice for at any rate the next three years, and I hope for many years to come, on terms satisfactory both to the Board and yourself, [...]
MARCONI'S WIRELESS TELEGRAPH Co. LTD.,
S Flood Page
Managing Director

Marconi having made sure that the full credit for the transatlantic success will belong to him, sweetens the deal with Professor Fleming by a private offer. As master of the situation, probably out of admiration, respect and gratitude for Fleming agreeing to his wishes and out of sheer business sense, he wrote a hand-written letter to Fleming offering him 500 company shares: to make him a part of the 'family'. This offer was specially private and as we will explore later, was not disclosed by Marconi to any other company officials including the Managing Director Major Flood Page.

[Marconi to Fleming; writing from his hotel in Poole, Dorset: 'private' note.]

10th Dec. 1900
Dear Dr. Fleming,
I wish you to know of a thing I have had in my mind for some time.
You are and have been working so hard, helping me in so many ways towards making the long-distance trial a success, which as you understand would mean a great deal to me, that I have determined in the event of our being able to signal across the Atlantic, to transfer to you 500 (five hundred) shares in Marconi's Wireless Telegraph Co. Ltd.
I very much hope you will accept my proposal which would be quite independent of anything the Company might think fit to do.
I believe the shares will be very valuable if we get across.
In haste, [...]
G. Marconi

Thus began the epoch-making effort of wireless signalling across the mighty Atlantic Ocean.


(Private)
Haven Hotel
Sandbanks
Poole
Dorset.
11th Dec 1900
Dear Dr Fleming.
I wish you to know of a thing I have had in my mind for some time.
You are and have

9. Acknowledgements

I am grateful to Hon Gioia Marconi Braga, Guglielmo Marconi's second daughter, for firing-up my interest in her father and for providing me with valuable information and references that launched this research. I am also very grateful to Mr Roy Rodwell of GEC-Marconi and Ms G Furlong and Ms S Stead, Manuscripts and Rare Books Section, UCL Library for their invaluable help and permission to reproduce the letters of correspondence, which are published courtesy of GEC-Marconi Limited and The Librarian, University College London.

Fleming photo courtesy University College London

Marconi photo courtesy McClure's Magazine, February 1902

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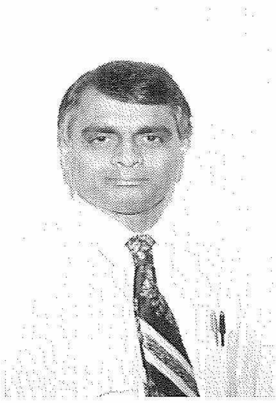

Probir K Bondyopadhyay was born on 26 September 1951 at Mahanad, India. He received the BTech(Honours) degree in Electronics and Electrical Communication Engineering from Indian Institute of Technology, Kharagpur, WB, India in June 1972, the MSEE and PhD degrees in Electrical Engineering, both from the Polytechnic Institute of New York in May 1977 and August 1982 respectively.

From August 1972 through June 1973 he was with Bharat Electronics Limited, Bangalore, India as an Assistant Engineer and from June 1973 through August 1975 he was with the Radar and Communication Center, IIT Kharagpur, India as a Scientific Officer. From September 1975 through September 1981 he was with the Polytechnic Institute of New York, Farmingdale, NY, first as a Senior Research Fellow in the EE department and then as a consultant to the Microwave Research Institute. From January 1981 through August 1987, he was with the Electrical Engineering and Computer Science departments of the New York Institute of Technology, Old Westbury, NY where, as the only Assistant Professor of EE, he played a pivotal role in winning the ABET accreditation for the newly created BSEE program. From May 1986 through September 1986 he was a Senior Software Engineer at EBASCO Services Ltd, World Trade Center, New York and from September 1986 through September 1988 he was an Associate Professor of EE at the State University of New York, Maritime College, Bronx, New York.

Since October 1988 he has been with the Electromagnetic Systems Branch, NASA Johnson Space Center, Houston, Texas where his activities are in the area of advanced satellite communications and is continuing his research and development works on phased array antennas at microwave and millimetre-wave frequencies.

The editors thank the referees for their assistance in evaluating this paper

Electromagnetics at Kuwait University: Role of Chiral Materials in Microwaves

Samir F Mahmoud

Kuwait University

Currently, the research administration unit at Kuwait University is supporting 327 research projects run by the staff members. Forty-seven other projects are partially or totally financed by outside sources such as Kuwait Foundation for the Advancement of Sciences (KFAS), Kuwait Institute for Scientific Research (KISR) and Environment Protection Council (EPC). Out of this total of 374 projects, 70 are in Engineering and the share of the Electrical and Computer Engineering Department is 23. These projects range from small projects of $7000 over one year to above $300 000 over 3 years. The Electromagnetic group in the department is taking up 4 projects with titles:

1. Antenna Systems for radiation and reception of nonsinusoidal waves.

2. Radiation, Doppler processing and Imaging with nonsinusoidal functions.

3. Ultrawideband Carrier-free Radar Polarimetry.

4. Microwave Circuit Components utilising Chiral Media.

This article will be restricted to a description of the fourth project in which I have been acting as the principal investigator for the last 2 years.

Background

Chiral materials belong to the family of biisotropic materials that exhibit magneto-electric coupling within their constitutive relations. Thus for time harmonic field variation one of the most commonly-used forms of the constitutive relations for chiral media is [*Jaggard et al,* 1979]

$$\begin{aligned} \mathbf{D} &= \varepsilon \mathbf{E} - i\zeta \mathbf{B} \\ \mathbf{H} &= \mathbf{B}/\mu - i\zeta \mathbf{E} \end{aligned} \qquad (1)$$

where $\mathbf{D}, \mathbf{E}, \mathbf{B}, \mathbf{H}$ are the vector electric flux density, the electric field, the magnetic flux density and the magnetic field respectively, ε is the permittivity, μ the permeability and ζ is the parameter that describes chirality. It has the dimensions of ohm^{-1}, hence known as the chiral admittance. Chirality is a synonym for handedness which is a geometrical property of a variety of 3-dimensional objects which lack bilateral symmetry. A definition of a chiral object is that it cannot be superimposed on its mirror image by translation and/or rotation. Obvious examples include spirals and helices which are described as either right-handed or left-handed. Historically, the phenomenon of "optical activity", or polarisation rotation of light, is associated with chiral materials as first conjectured by *Pasteur* [1848], who postulated that chiral materials offer unequal phase velocities to circularly-polarised waves of opposite handedness. Experimental work on microwave chiral materials was probably started by *Lindman* [1922] who devised a macroscopic model of a chiral material by using a random collection of arbitrarily-oriented helices in a dielectric host medium. With helices sized such that they interact with microwaves, the phenomenon of polarisation rotation was then detected. On the theoretical side, *Jaggard et al* [1979] have shown that for a collection of randomly oriented helices of the same handedness (or chirality), an applied electric field induces a magnetic moment and an applied magnetic field induces an electric polarisation, thus leading to the constitutive relations in (1). The sign of ζ there depends on the handedness of the medium; ie whether right-handed or left-handed. A very good and extensive coverage of chiral material history as well as some recent applications is found in an article by *Engheta and Jaggard* [1988].

Now, combining (1) with Maxwell's two curl equations leads to :

$$-\nabla^2 \begin{pmatrix} \mathbf{E} \\ \mathbf{H} \end{pmatrix} = k^2 \begin{pmatrix} 1+2c^2 & 2i\eta c \\ 2i\eta^{-1}c(1+c^2) & 1+2c^2 \end{pmatrix} \begin{pmatrix} \mathbf{E} \\ \mathbf{H} \end{pmatrix} \qquad (2)$$

where $k = \omega(\mu\varepsilon)^{1/2}$, $\eta = (\mu/\varepsilon)^{1/2}$ and c is a normalised chiral admittance defined by $c = \zeta\eta$.

Equation (2) shows that in a chiral medium, the wave equations for $\mathbf{E}$ and $\mathbf{H}$ are coupled. However, one can get decoupled fields by finding the eigenvalues and eigenvectors of the 2x2 matrix in (2). So, equating the RHS by $k_c^2(\mathbf{E} \;\; \mathbf{H})^t$ and solving for the eigenvalues k_c, we get:

$$k_c \equiv k_{\pm} = k\left[\sqrt{1+c^2} \pm c\right] \qquad (3)$$

The corresponding two pairs of eigenvectors are :

$$\mathbf{E}_+ \equiv \mathbf{R}, \mathbf{H}_+ = i\eta_c^{-1}\mathbf{R}$$
and (4, 5)
$$\mathbf{E}_- \equiv \mathbf{L}, \mathbf{H}_- = -i\eta_c^{-1}\mathbf{L}$$

where $\eta_c = \eta / \left(1+c^2\right)^{1/2}$ is a characteristic chiral impedance. Here the vectors **R** and **L** symbolise right circularly polarised (RCP) and left circularly polarised (LCP) vectors as will be shown soon. Both solutions in (4) and (5) are characterised by the fact that in each of them **E** and **H** are identical except for a $\pi/2$ time-phase difference. Now, using the first curl equation of Maxwell: $\nabla \mathrm{x} \mathbf{E} = -i\omega \mathbf{B}$, with **E** and **H** in (4) and **B** in (1) we arrive at the simple relation:

$$\nabla \times \mathbf{R} = k_+ \mathbf{R} \tag{6}$$

Similarly

$$\nabla \times \mathbf{L} = -k_- \mathbf{L} \tag{7}$$

In the special case of a plane travelling wave $\exp(i\omega t - ik_\pm z)$ along z, (6) and (7) reduce respectively to:

$$\hat{\mathbf{z}} \times \mathbf{R} = i\mathbf{R}, \quad \text{and} \quad \hat{\mathbf{z}} \times \mathbf{L} = -i\mathbf{L}$$

showing that apart from an arbitrary constant,

$$\mathbf{R} = \hat{\mathbf{x}} - i\hat{\mathbf{y}}, \quad \text{and} \quad \mathbf{L} = \hat{\mathbf{x}} + i\hat{\mathbf{y}}$$

in a cartesian frame with unit vectors $(\hat{\mathbf{x}}, \hat{\mathbf{y}}, \hat{\mathbf{z}})$. Therefore **R** is an RCP wave with wavenumber k_+ and **L** is an LCP wave with wavenumber k_- as we have anticipated. This is the property of birefringence which opens the way for chiral media to play a role in microwave circuits. Recently, a surge of technical papers has been published on new possible applications of chiral materials and a special issue of JEWA was devoted to their interaction with microwaves. To give just few examples of these applications, we mention studies on reduction of radar cross-section of chiral coated planar surfaces (*Liu and Jaggard,* 1992, *Jaggard and Liu,* 1992 and *Garlia, Uslenghi and Yu,* 1992), Chirostrip antennas (*Pelet and Engheta,* 1992), Antennas in open chiral medium (*Jaggard et al,* 1988 and *Engheta et al,* 1989). Guided waves in chiral filled waveguides, or chirowaveguides as now known (*Engheta et al* 1989), have been studied by several authors including *Engheta and Pelet* (1990), *Eftimiu and Pearson* (1989), *Svedin* (1990), *Hollinger et al* (1991) and the present author (1992 a, b, c, 1993 a, b). Other relevant papers are listed in the additional list of references.

In the following two sections we review the main features of modes in chirowaveguides, then we consider a class of chirowaveguides with low crosspolarisation modes.

Mode character in chirowaveguides

In this section we give a brief account of modal propagation in chirowaveguides which we define here as waveguides with total or partial filling with a chiral material. So let us consider a uniform cylindrical chirowaveguide with axis along the z direction. Considering source-free modes propagating along z with dependence as $\exp(i\omega t - i\beta z)$, we may express the longitudinal E and H field components within the chiral regions:

$$E_z = C_1 R_z + C_2 L_z$$
$$-i\eta_c H_z = C_1 R_z - C_2 L_z \tag{8, 9}$$

where we've made use of (4) and (5) and introduced the arbitrary constants C_1 and C_2. The transverse field components have the same forms as (8) and (9) except for using the transverse components of R and L in place of the longitudinal components. The former ones can be related to the latter by using (6) and (7) whence we get:

$$\mathbf{R}_t = \frac{-i\beta \nabla_t R_z + k_+ \nabla_t R_z \times \hat{\mathbf{z}}}{k_+^2 - \beta^2}$$
$$\mathbf{L}_t = \frac{-i\beta \nabla_t L_z - k_- \nabla_t L_z \times \hat{\mathbf{z}}}{k_-^2 - \beta^2} \tag{10, 11}$$

Finally, noting that $\mathbf{R}_z$ and $\mathbf{L}_z$ satisfy the wave equations $\nabla^2 \psi + k_\pm^2 \psi = 0$ with k_+ and k_- respectively, we realise that we have all ingredients to write down all field components in a chiral region.

Before considering specific chirowaveguides, let us find out some general properties. First, because of the coupling between electric and magnetic fields in the same direction through the chiral admittance (see(1)), one can show that no TE nor TM modes are possible in a chirowaveguide, so that all modes are hybrid (*Engheta and Pelet,* 1989). Second, since the modal field in a chiral medium is a superposition of R (almost RCP) and L (almost LCP) vector fields, it is generally elliptically polarised with polarisation that depends on position and frequency. In partially-filled waveguides where a chiral material is slightly perturbing the modes, it has been shown by *Viitanen and Lindell* (1992) that the perturbation in β is proportional to $i\zeta \mathbf{E}.\mathbf{H}$ integrated over the cross section. This requires that **E** and **H** have the same direction and a $\pi/2$ time-phase shift in order to have

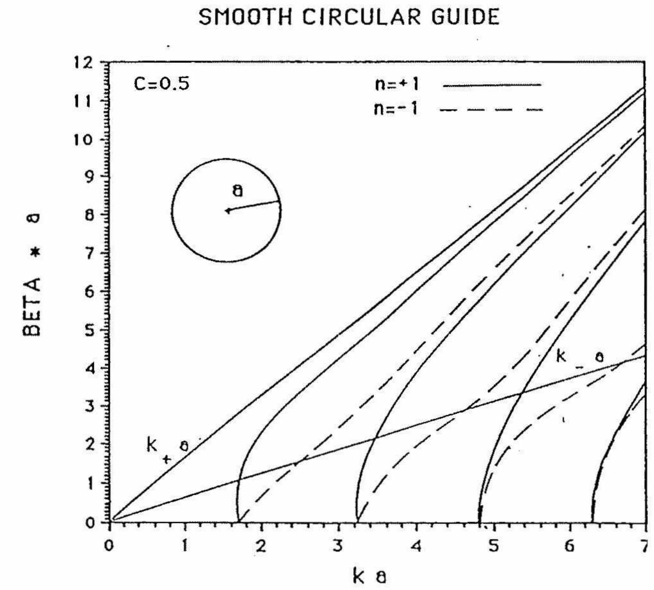

Fig 1: Normalised modal wavenumber versus ka *for modes with* $n = \pm 1$ *in a chirowaveguide with perfect electric wall.*

effective perturbation. Only hybrid mode-supporting structures can satisfy this condition. Next let us consider modal propagation in circular cylindrical chirowaveguides.

Circular cylindrical chirowaveguides

Consider a circular cylindrical waveguide of radius a and perfectly conducting electric wall that is totally filled with a chiral material of parameters $(\varepsilon, \mu, \zeta)$. To find the natural modes, we resort to (8)-(11). Appropriate field dependence for the longitudinal components R_z and L_z apart from the $\exp(i\omega t - i\beta z)$ factor, are:

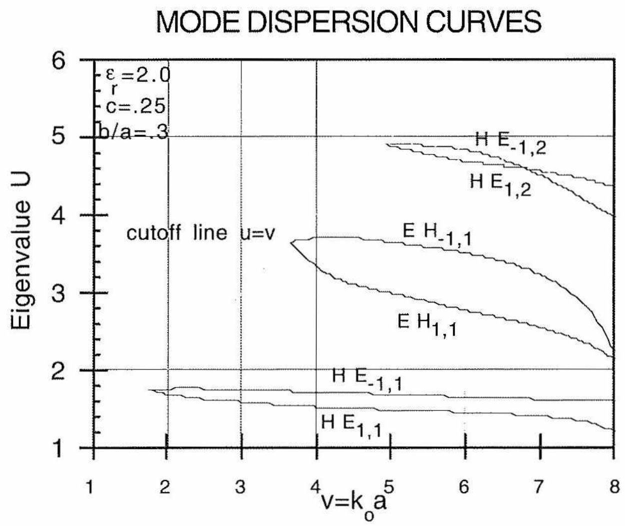

Fig 2: Dispersion curves for a chiral rod loaded waveguide with perfect electric walls.

$$R_z(\rho, \varphi) = J_m(r\rho)\exp(-in\varphi)$$

$$L_z(\rho, \varphi) = J_m(l\rho)\exp(-in\varphi) \qquad (12, 13)$$

where $J(.)$ is the Bessel function of first kind, r and l are transverse wavenumbers given by $\left(k_\pm^2 - \beta^2\right)^{1/2}$ respectively, m is a positive integer and n is a positive or negative integer, but m=|n|. Now, it is straightforward to write down all field components from (8)-(11), particularly E_z and E_φ which must vanish at the electric wall $\rho = a$. The result is two homogeneous equations whose determinant of coefficients must vanish, hence providing the following modal equation for β (*Mahmoud,* 1992 b):

$$k_+G(u_r) + k_-G(u_l) + n\beta\left(u_r^{-2} - u_l^{-2}\right) = 0 \qquad (14)$$

where $u_r = ra$, $u_l = la$, and $G(u)$ is defined by:

$$G(u) = \left[(d/du)J_m(u)\right]/uJ_m(u) \qquad (15)$$

It is striking to notice that solutions of (14) depend on the sign of n, so that a pair of modes with $n = +m$ and $n = -m$; ie with azimuthal variation have different values of β. However, when β is zero, (14) does not depend on n, signifying that the pair of modes with $n = \pm m$ share the same cutoff frequency. This is a characteristic property of chirowaveguides, known as mode bifurcation, that has been first revealed by *Engheta and Pelet* (1989) in connection with a two-parallel-plate chirowaveguide and discussed by *Hollinger et al* (1991) and *Mahmoud* (1992 b) for circular chirowaveguides. A sample of mode dispersion curves in a circular chirowaveguide for modes with $n = 1$ and $n = -1$ is shown in Fig 1. It is important to note that βa for all modes approach the asymptote k_+a for sufficiently high frequencies, whence all modes approach the RCP state (for right hand chirality).

It is interesting to note that if the perfect electric wall is replaced by a perfect magnetic wall, the modal equation (14) will remain unchanged. The only change will be the sign reversal of the ratio C_2/C_1 signifying the reversals of the roles of E and H in accordance with duality rules (see (8)-(9)).

Next we consider partial chiral loading by an axial chiral rod in an otherwise empty waveguide. For definiteness, the circular waveguide has a radius a and is air-filled except for the region $\rho \le b < a$ which is occupied by a chiral rod. The modal equation in this case has been derived and solved in *Mahmoud* [1994]. An example of results is given in Fig 2 where the modal eigenvalue u defined by $u = \sqrt{k_o^2 - \beta^2}\, a$ is plotted versus $k_o a$; k_o being the bulk wavenumber in air. The line $u = V(\equiv k_o a)$ in the figure is the locus of mode cutoffs since on this line $\beta = 0$. Mode bifurcation is manifested in this figure by having the pairs of modes $HE_{\pm n,s}$ or $EH_{\pm n,s}$ with one cutoff frequency but different 'β's above cutoff.

A study of the polarisation states of the lower order modes with $n = \pm 1$ (*Mahmoud,* 1992 b) reveals that for $n = +1$ modes, the major polarisation is right circular polarisation (RCP). Conversely for $n = -1$ modes, the major polarisation is left circular polarisation (LCP). So, if the partially-loaded waveguide under consideration is fed by an empty guide of the same size and carrying the dominant mode HE_{11}, the pair of modes $HE_{\pm 1,1}$ will be the strongest to be exited. Since the two 'β's of this pair are different, interference will occur between the two oppositely circularly polarised modes. If the feeding HE_{11} mode is linearly polarised, the polarisation in the partially-loaded guide is expected to rotate in the transverse plane at a rate of $(\Delta\beta)/2$ radian per unit length. A polarisation rotation length L_r may be defined as the axial length in which the polarisation rotates by 90°; hence $L_r = \pi / \Delta\beta$. To demonstrate the dependence of L_r on the chiral rod parameters, it is plotted versus $k_o a$ with b/a as a parameter in Fig 3. As expected L_r decreases with increased chiral rod size.

Chirowaveguides eith highly polarised modes

From the previous section, we see that the modal fields in a chirowaveguide are generally a superposition of RCP and LCP components. This is a reflection of the chiral medium birefringence; that is having two unequal wave-numbers k_+ and k_- for the RCP and LCP waves. However a question can be posed as follows: can modal fields be purely RCP or purely LCP and under what conditions will this occur?. To answer this question let us consider a circular cylindrical chirowaveguide whose wall is characterised by a specified finite impedance tensor. Namely, a general wall boundary condition at $\rho = a$ (*Wait,* 1985):

$$E_\varphi = Z H_z + p E_z$$
$$H_\varphi = -Y E_z + p H_z \qquad (16)$$

where Z and Y are surface impedance and admittance which are generally mode dependent; ie they depend on β and n, while p is a dimensionless parameter which is also mode dependent. Using the field components obtained from (8)-(11) in (16) we get the following two equations in the constants C1 and C_2:

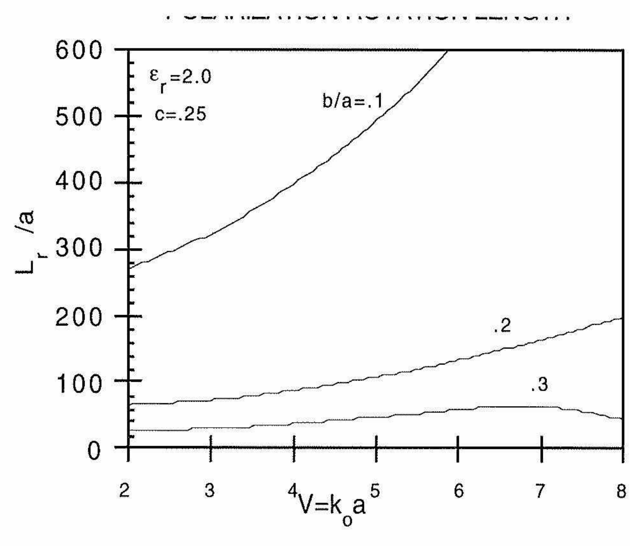

Fig 3: Variation of rotation length versus V for different chiral rod size.

$$C_1\left(\hat{Z} - F_n(ra, k_+ a)\right) J_m(ra) - C_2\left(\hat{Z} - F_{-n}(la, k_- a)\right) J_m(la) = 0$$

$$(17, 18)$$

$$C_1\left(\hat{Y} - F_n(ra, k_+ a)\right) J_m(ra) + C_2\left(\hat{Y} - F_{-n}(la, k_- a)\right) J_m(la) = 0$$

where $F_n(u,v) = (v/u)J'_m(u)/J_m(u) + \beta n a / u^2 + p$

$\hat{Z}$ and $\hat{Y}$ are normalised such that

$$\hat{Z} = -iZ/\eta_c \text{ and } \hat{Y} = -iY\eta_c$$

A careful investigation of (17) and (18) shows that in the special case $\hat{Z} = \hat{Y}$, there are two distinct sets of solutions given by (i) and (ii) below:

$$\hat{Z} = F_n(ra, k_+ a) \quad \text{and} \quad C_2 = 0 \qquad \text{(i) (19)}$$

$$\hat{Z} = F_{-n}(la, k_- a) \quad \text{and} \quad C_1 = 0 \qquad \text{(ii) (20)}$$

So modes lie in two categories governed by (19) and (20) respectively. In category (i) the chiral medium behaves as a simple monorefringent medium having a single wavenumber k_+ and in category (ii), it behaves as having a single wavenumber k_-. A study of the polarisation states of modes in these two categories show that the polarisation is dominantly RCP for modes in category (i) and dominantly LCP for modes in category (ii) (*Mahmoud,* 1992a). The degree of polarisation purity depends on how close the wavenumber β is to $k_{\pm}$. For example the transverse electric field for modes satisfying (19) and having $n = +1$ is given by (*Mahmoud*, 1992a):

$$\mathbf{E}_t(\rho,\varphi) = J_o(r\rho)(k_+ + \beta)(\hat{\mathbf{x}} - i\hat{\mathbf{y}}) + J_2(r\rho)(k_+ - \beta)(\hat{\mathbf{x}} + i\hat{\mathbf{y}})\exp(-2i\varphi) \quad (21)$$

The first term is purely RCP while the second is LCP. A crosspolar ratio XCP may be defined as proportional to the (minor/major) circular polarisation amplitudes. Under the condition $\hat{Z} = \hat{Y}$, we write:

$$XCP = |k_{\pm} - \beta| / (k_{\pm} + \beta)$$

for modes in categories (i) and (ii) respectively. Now we consider two types of chirowaveguides that can satisfy the condition $\hat{Z} = \hat{Y}$. These are the transversely corrugated wall guide and the dielectric line wall guide as depicted in Fig 4a, b.

1. The transversely corrugated wall guide (Fig 4a)

The corrugations are assumed to be air-filled while the chiral material fills the inner region $\rho \le a$. For a sufficiently large number of corrugations per a free-space wavelength, a simple model for the wall can be adopted (eg *Clarricoats and Olver*, 1984) which yields $\hat{Z} = 0,\ p = 0$ and $\hat{Y}$ is mainly dependent on the slot depth and the free space wavenumber; namely $\hat{Y} \approx \cot(k_o t) + 1/2k_0 a$. Thus $\hat{Y}$ can be rendered zero at a given wavelength by adjusting the slot depth t. As a numerical example a plot of βa versus $k_+ a$ for modes of category (i) in a corrugated wall chirowaveguide with $\hat{Z} = \hat{Y} = 0$ is shown in Fig 5. It is noted that modes with $n = \pm 1$ have different βa, but the same cutoff frequency. The latter is simply given by the $k_+ a =$ roots of $J_1'(x)$. The results in Fig 5 are equally valid for modes of category (ii) if $k_+ a$ on the abscissa is replaced by $k_- a$ and n changes sign.

2. The dielectric lined wall chirowaveguide (Fig 4b)

By lining the smooth wall waveguide by a dielectric material having a relative dielectric constant $\varepsilon_{rel} < \beta / k_o$ and appropriate thickness, the condition $\hat{Z} = \hat{Y}$ required for highly polarised modes can be satisfied at a given frequency (*Mahmoud*, 1991, 1993a). Generally, the wall parameters $\hat{Z}, \hat{Y}$ and p are functions of β but they vary sufficiently slowly with it that we can only consider the value $\beta = k_+$ for the low order modes of interest. An important and practical

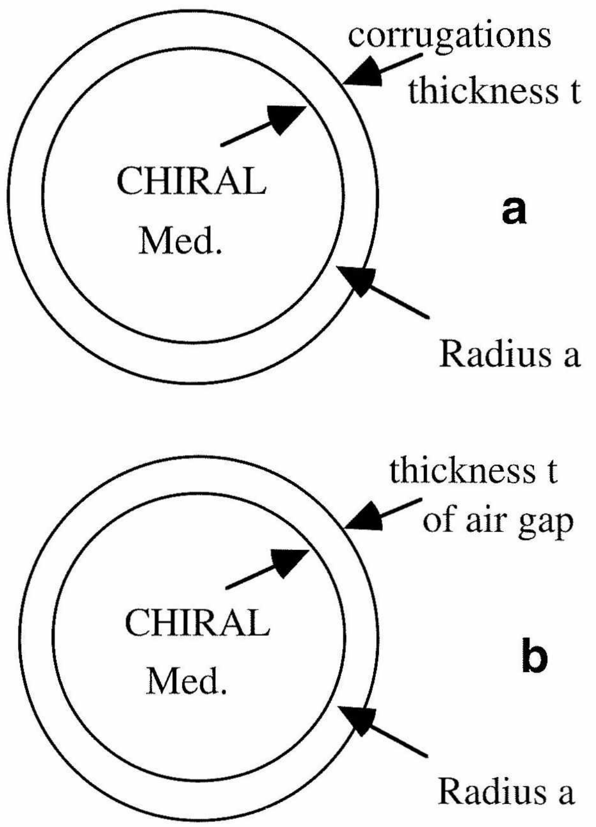

Fig 4: Waveguides with impedance walls: a) transversely corrugated walls, b) dielectric lined walls.

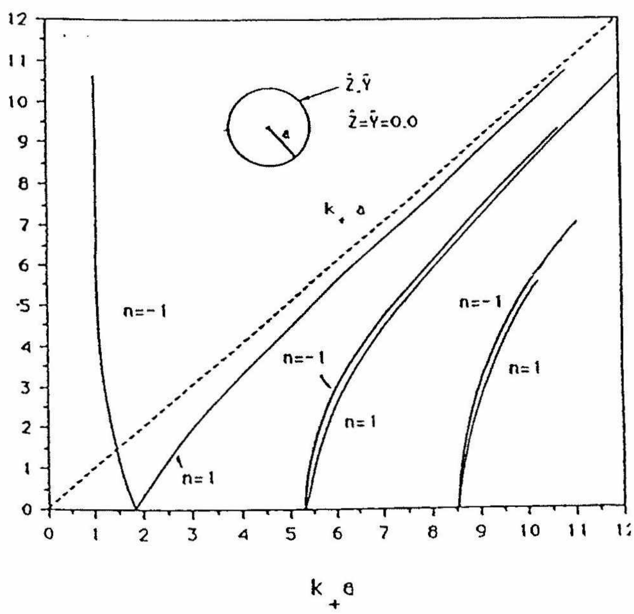

Fig 5: Normalised modal wavenumber βa versus $k_+ a$ for category (i) modes in a circular corrugated waveguide with wall parameters $\hat{Z} = \hat{Y} = 0, n = \pm 1$.

case of interest is to choose air for the dielectric lining so that we end up with an air gap next to wall. A numerical example showing the variation of the wall parameters with *ka* for a fixed air gap and given chiral material parameters is given in Fig 6. Here the condition $\hat{Z} = \hat{Y}$ is satisfied at $ka = 12$. The modal normalised wavenumbers β / k are plotted versus *ka* for the lowest six modes labelled by ($\pm$1s) in Fig 7. It is observed that, for all modes, β approaches k_+ at sufficiently high *ka*. However, some modes with $n = -1$, such as the (-1,3) mode can have a range of *ka* in which β is close to k_- ($8 \le ka \le 11$). Within this range, the mode is mostly LCP but eventually turns to be RCP as *ka* increases. The crosspolarisation ratio XCP is plotted in dB for the first 3 modes with n=+1 and the (-1,3) mode in Fig 8. In accordance with the above argument the XCP is seen to be small (say <-40 dB) above a certain minimum *ka* for each mode with n=+1. The mode (-1,3) has a major LCP and a low XCP in a range of *ka* between 8 and 11.

Surface wave modes on a chiral circular cylindrical rod have also been studied by several authors including *Cory and Tamir* (1992) and *Mahmoud* (1993b). It has been shown that modes are split into two categories with chiral bulk wavenumber either equal to k_+ or k_- when the condition $\eta_c = \eta_o$ is satisfied; ie when the chiral and outside medium impedances are equal (*Mahmoud,* 1993b). Under this condition, modes will be highly RCP over wide bandwidths with high frequency open end, or highly LCP over a finite bandwidth.

CONCLUSIONS

A brief review on chiral materials has been presented with emphasis on potential applications in microwaves. Study of modal propagation in chirowaveguides reveals the phenomenon of mode bifurcation; that is the appearance of modes in pairs with one cutoff frequency but two different propagation constants at higher frequencies. As a result, interference between the fields of the dominant pair of modes causes changes in the polarisation states of the fields as they propagate down the guide. For example, a chirowaveguide excited by a linearly polarised field, exhibits polarisation rotation as demonstrated in Fig 3. Mode bifurcation is a direct result of the chiral medium birefringence.

A class of chirowaveguides with finite impedance and admittance walls are studied. It is shown that under the condition (see 16-18), the modes lie into two categories in which the chiral medium behaves as having a single, rather than two, bulk wavenumbers which is either k_+ or k_-. The modes are then either highly RCP or LCP. Two guiding structures that are capable of satisfying these conditions at one frequency, are studied. Numerical results show that, for right handed chirality, modes with mostly RCP fields can be maintained over a very wide band; with open ended high

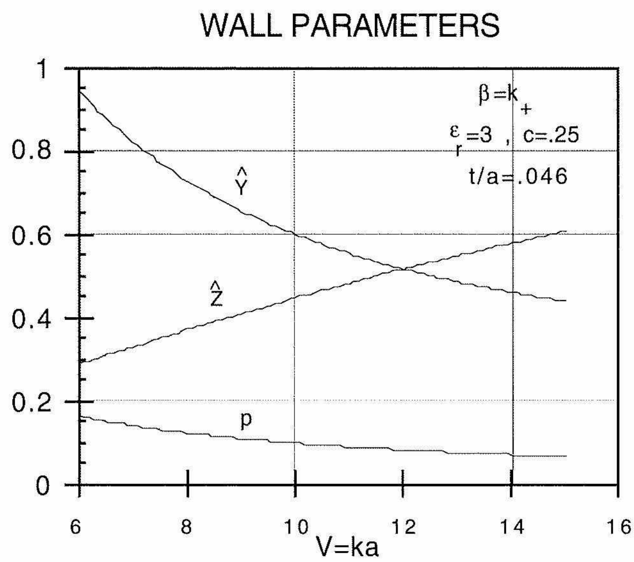

Fig 6: Normalised wall parameters of an air gap loaded chirowaveguide versus normalised frequency.

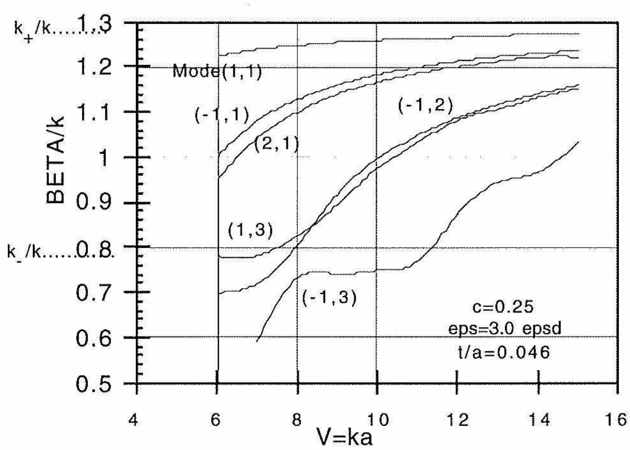

Fig 7: The modal wavenumber β / k versus normalised frequency for the first six lower order modes of an air gap loaded chirowaveguide.

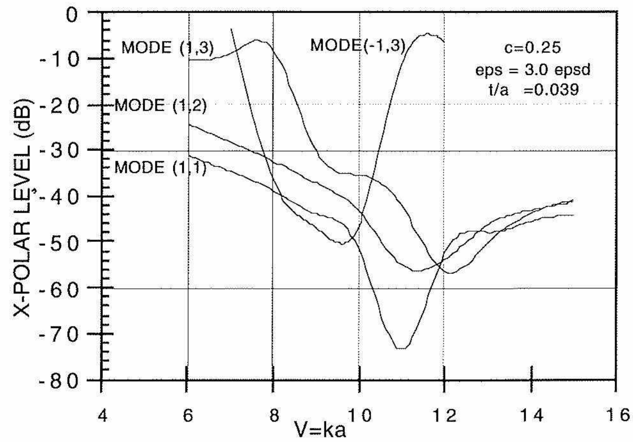

Fig 8: XCP levels in dB for the first 3 modes with n=+1 *and the mode (-1, 3) for an air gap loaded chirowaveguide.*

frequencies. On the other hand, some modes with mostly LCP fields can be maintained over a finite passband. At sufficiently high frequencies, each mode tends to become RCP. Such waveguides can find applications in microwave schemes utilising polarisation diversity technique for efficient spectral use.

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The Radiation Risks - Are They Real?

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General Considerations

Electromagnetic (EM) fields are now part of our environment. Sources of EM radiation include radio and television broadcast antennas, radar antennas from air traffic control systems and other civil and military applications and numerous telecommunications systems including hand-held transceivers for mobile communication. With an increasing public awareness of environmental issues comes a perception that exposure to EM fields may be detrimental to health. The public has the right to question the issue and to expect the scientists to consider matters, perform the necessary research and provide as many answers as possible.

The main issue is that of biological effects resulting from the interaction of EM fields with living organisms including people. The extensive body of literature on this and related subjects enables the following statements to be made for exposure to EM fields in the frequency range 10 MHz to 10 GHz.

- When a person is exposed to EM radiation the incident external fields induce internal fields within the body. The internal fields interact with the body tissues at various levels of organisation and result in induced currents and energy absorption.
- The degree of energy coupling depends mainly on the field parameters and on the shape and size of the exposed person.
- Generally, when the rate of energy absorption during exposure exceeds the rate of energy dissipation, the body temperature rises. Most of the biological effects of EM fields are an indirect consequence of this thermal stimulation and are therefore known as thermal effects.
- There is a strong correlation between the intensity of the internal fields and the severity of the biological effect. Internal fields are quantified in terms of the rate of energy they deliver per unit body mass, this quantity is known as the specific absorption rate (SAR) and is expressed in watts per kilogram (W/kg).
- There is a threshold whole body SAR above which there is an increasing likelihood of adverse health effects.
- The concept of whole body SAR is not sufficient to guard against adverse biological effect in exposure situations where acute localised heating is likely to occur. The partial body exposure to the non-uniform fields from hand-held transceivers results in complex field distribution within the body. The shape and layered structure of the tissues of the head make it particularly prone to non-uniform field distributions. In terms of SAR, the field patterns are further accentuated by differences in the electrical properties of the tissues.
- Excessive localised heating may cause undesirable biological effects. Exposure of the head must be regulated to avoid localised heating of the lens of the eye and certain areas of the brain, such as the hypothalamus, which may be particularly sensitive to temperature rises.
- To safeguard against localised overheating restrictions on SAR averaged over small masses of tissue must be postulated.

Exposure standards developed by National and International Bodies are almost exclusively based on threshold whole-body SAR and localised heating. They are formulated to guard against thermal effects.

Low-level exposures that result in SAR below the level of thermal significance are implicitly assumed safe, but are they? A number of studies have reported biological responses associated with low-level exposures. Such manifestations are known as athermal effects. The evidence for such effects is ambiguous, the associated mechanisms of interaction have not been elucidated and their health implications, if any, are not clear.

Although there are no specific athermal biological effects ascribed to microwaves, the possibility remains a source of public concern. The debate over the potential health hazard of exposure to low levels of microwaves was recently reopened over allegations in the press of a relationship between the use of portable communication equipment and the development of brain cancer. This view is not supported by the scientific evidence.

The question of cancer was recently investigated by the UK National Radiological Protection Board (NRPB) whose advisory group on non-ionising radiation, under the chairmanship of Sir Richard Doll, has studied the evidence on the likelihood of a relationship between EM fields and the risk of cancer. The Group published its report [1] in 1992 and concluded that, taken overall, the data do not provide any firm evidence that there is any link between the incidence of cancer and exposure to EM fields.

The latest wave of public concern over the safety of portable telephones remained in the public domain until the release,

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by the US Food and Drug Administration (FDA), in February 1992, of an advisory note on cellular telephones [2]. The FDA's view is that there is no proof of a link between the exposure to radiation from a cellular telephone and cancer but there is also not enough information to refute the possibility of a risk. This is also the opinion of the International Commission on Non-ionising Radiation Protection put forward in a position statement [3] released by the Institute of Electrical and Electronics Engineers (IEEE) in May 1992.

Dosimetric considerations

Safety considerations are formulated in terms of SARs by imposing a safety factor on the threshold SAR value for the onset of thermal effects. Such safety measures can only be implemented by correlating them to corresponding external field values that are amenable to measurement such as electric and magnetic field strengths in the absence of the body. This is the role of theoretical and experimental EM dosimetry.

The dosimetry of hand-held transceivers calls for special considerations. Because of the proximity of the emitting antenna to the body, the external electric and magnetic fields are not simply related to one another in phase, direction or magnitude, they may vary rapidly from one point to another and cannot, therefore, be used as a measure of the induced SAR values. Instead, theoretical models and numerical techniques are used to simulate the exposure and calculate the resulting SAR values.

The nature of the microwave fields and the complexity of their interaction with the body result in highly non-uniform energy deposition in the head. The calculation of the spatial distribution of energy absorption under these conditions is not a trivial matter even for the relatively simple situation of plane wave irradiation [4, 5]. It has been shown that for plane wave irradiation there are combinations of head-sizes and frequencies of irradiation that will result in a concentration of energy in the brain and in the eyes. World-wide, there are at least four main studies underway dedicated to the measurement and calculation of energy absorption in the head from hand-held transceivers under the realistic conditions of near-field exposure. The availability of data from these studies will help the implementation of the safety guidelines in force, thus guarding the user of these transceivers against thermal effects.

Exposure Standards

The protection philosophy implemented in EM exposure standards applies irrespective of the source of radiation. However, under conditions of non-uniform fields and partial body exposure, such as exposure from hand-held transceivers, compliance with the standard requires complex and specialised dosimetric calculations. A practical way to cope with such situations is for Standard Setting Bodies to use the available dosimetric information to define exclusion clauses based on the device power output. This approach was adopted by the International Non-Ionising Radiation Committee (INIRC) of the International Radiation Protection Association (IRPA) in their 1988 IRPA/INIRC guidelines [6] for devices of output power less than 7 W. Implicit in this clause is an obligation on manufacturers of these devices to ensure that, when used as intended, they do not give rise to exposure conditions that contravene the protection philosophy. Some recent dosimetric studies [7] suggest that this may not always be the case and that, under certain conditions, exposures from hand-held 7 W devices may result in the safety considerations being exceeded. It is therefore, almost certain, that this exclusion clause will be revoked or modified in the forthcoming revision of the guidelines. The (American) Institute of Electric and Electronics Engineers (IEEE) have adopted a more stringent limit in the 1991 revision of their guidelines [8].

The European Committee for Electrotechnical Standardisation CENELEC has set up a Technical Committee (TC111) to study and report on human exposure to EM fields. TC111 has assigned to its sub-committee SC111B the task of preparing an exposure standard for the protection of people against EM fields in the frequency range 10 kHz to 300 GHz. A draft of this document dated August 1993 was circulated to all interested parties for consultation and comments. The document makes no reference to hand-held telecommunication equipment and there are no exclusion clauses.

In October 1993, the Directorate General III (DGIII) of the Commission of the European Communities issued a Standardisation Mandate to CENELEC concerning the safety requirements for mobile communication in the frequency range 30 MHz to 6 GHz. The proposed standard should define the safety requirements to protect the users of mobile telecommunications from thermal effects. In view of the uncertainties concerning the nature and biological significance of athermal effects, DGIII issued a mandate to CENELEC for the preparation of a work programme on athermal effects in the mobile communications frequency range. The work anticipated by the mandates falls within the scope of and has been assigned to SC111B.

Conclusions

On present knowledge, the concepts of threshold whole body SAR and SAR averaged over a small mass of tissue are adequate to protect users of hand-held transceivers. These are the protection concepts in most current national and international standards.

Exposures that result in SARs below the level of thermal significance are implicitly assumed safe. However, it is generally agreed that there is a need for further research to improve and consolidate our understanding of athermal responses and their biological significance.

For users of hand-held transceivers, the implementation of the above protection philosophy requires the mediation of realistic dosimetric studies. These are complex theoretical and numerical techniques to simulate the SAR distribution in the body under specific exposure conditions. Such studies play an essential role in the formulation of a protection policy for users of mobile communications equipment.

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The editors thank the referees for their assistance in evaluating this paper

JATP MARKS BEYNON'S BIRTHDAY

[The following item originally appeared as a preface to a special issue of Journal of Atmospheric and Terrestial Physics, volume 5 no 7. Following two terms (1966 - 1972) as a Vice President of URSI, Sir Granville was President of URSI during 1972 - 1975. The Radioscientist editors are pleased to join JATP in this celebration.]

Sir Granville Beynon's eightieth birthday on 24 May 1994

Michael J Rycroft

Editor-in-chief, Journal of Atmospheric and Terrestial Physics, Cranfield University, Bedford, England

Professor Sir Granville Beynon, a grand old man of British radio science, celebrates his eightieth birthday on 24 May 1994. To mark this occasion, the seventh issue of volume 56 of the *Journal of Atmospheric and Terrestrial Physics* contains fifteen papers on Sir Granville – the man and his work. It also contains some historic photographs and Sir Granville's publication list.

Professor Lance Thomas recalls three phases of his association with Sir Granville, first as a postgraduate student, secondly whilst at Slough, and thirdly as Sir Granville's successor at Aberystwyth. Geoffrey Brown offers "some radio reflections", recalling some personal and scientific associations with Sir Granville Beynon over forty six years. Professor Phil Williams briefly reviews fifty years of work on ionospheric movements, TIDs and tidal modes. Dr John O Thomas recollects his early days of research with Sir Granville, the advent of satellites and the application of radars in remote sensing. Professor Tudor Jones, Sir Granville's last postgraduate student at Swansea and first postdoctoral worker at Aberystwyth, recalls his training in ionospheric physics and radio propagation.

Dr Basil Briggs, who most sadly died before seeing this issue, reviews Sir Granville's – and later – work on the spaced-receiver technique for the measurement of ionospheric winds and the study of atmospheric irregularities. Dr Geoffrey Goodwin recalls his work on this topic at Swansea at the start of the International Geophysical Year in 1957.

Mrs Yela Bogitch and Professor Bill Gordon recall some of Sir Granville's many contributions to the activities of URSI. Professor Tor Hagfors mentions Sir Granville's invaluable contributions to EISCAT.

Professor A P Mitra emphasises the assistance that Sir Granville gave to scientists in developing countries and his influence on international programmes, a theme developed further by Alan Shapley. Dr Stanley Ruttenberg and Professor Henry Rishbeth review the ICSU system of World Data Centres, established at the start of the International Geophysical Year. Finally, Dr David Willis, Professor Tony Hewish, Professor Henry Rishbeth and I give a resumé of a recent Royal Society report on synoptic data for solar-terrestrial monitoring in the United Kingdom, the initiation of which came from Professor Sir Granville Beynon.

ELECTRONIC URSI NEWS

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Tutorial on electromagnetic response of thin layered conductor/insulator composites

James R Wait

*ECE Dept, University of Arizona**

Abstract

Beginning with fundamental principles, the appropriate boundary conditions are developed for a thin resistive or semi-insulating layer bounded by two homogeneous conducting half-spaces. The model is then extended to treat both a highly conducting sheet and a resistive thin sheet. The response of a plane wave at oblique incidence is then considered for this combined model. It is shown that the results are consistent with an exact treatment using two slabs of finite thickness. Such a solution reduces to the thin composite layer when a suitable limit is taken. Finally, the thin layer formalism is generalised to a thin sandwich-like or laminated structure where the individual laminations are alternating good and poor conductors.

Introduction

Laminated materials consisting of metal and fibre layers are now employed in many fabrication technologies. From the standpoint of weight and strength, they have many advantages over non-laminated materials. The main disadvantage is the inferior electromagnetic shielding property of such a laminated structure although there may be exceptions to this rule.

There is a need to evaluate the electromagnetic characteristics of such layered composites in a quantitative yet simple fashion. To illustrate the problem, we will begin with a simple example of a thin resistive layer between two homogeneous conducting half-spaces. The objective is to determine how the tangential electric fields, on opposite faces of the thin layer, are connected. We then extend the analysis to the case where this resistive layer is backed by a thin sheet of relatively high conductivity. Now the objective is to determine how both the tangential electric and the tangential magnetic fields are related on the two sides of the composite sandwich. For this situation, we develop a simple equivalent circuit which allows for the spatial variation of the tangential fields. Also we confirm that our derived circuit parameters are consistent with a general double slab formulation if we allow the two slabs to have small thickness but with one slab having very low conductivity and the other having very high conductivity. Finally, we generalise the analysis to allow any number of such composites to be considered (ie a compact club sandwich.)

There have been a number of analytical studies of conducting thin sheets in the context of electrical geophysics [1-7] allowing, in some cases, for lateral variations of the sheet parameters. Here we will restrict attention to lateral constancy of the sheet thicknesses and electrical properties but the primary or exciting fields can be arbitrary. Also, with exception of the work by Rokityansky [7], the combined effects of resistive and conductive sheets have not been examined hitherto. However it might be mentioned there is an analogy with the analyses by Lindell [8] who developed impedance operators for combined magnetic and electric current sheets. The author [9-10] had also considered some closely related problems for the transient electro-chemical response of spherical metal particles in electrolytical solutions.

Thin Sheet Boundary Conditions

First of all, let us consider the situation at the interface between two homogeneous conducting half-spaces as illustrated in Fig 1. The region x < 0 has a conductivity σ_b while the region $x > 0$ has a conductivity σ. Both σ_b and σ can be complex if we are dealing with time harmonic fields where the implied time factor is $\exp(j\omega t)$ where ω is the angular frequency. Now the intrinsic property of the interface is that the voltage drop across the interface is $\tilde{n} J_x$ volts

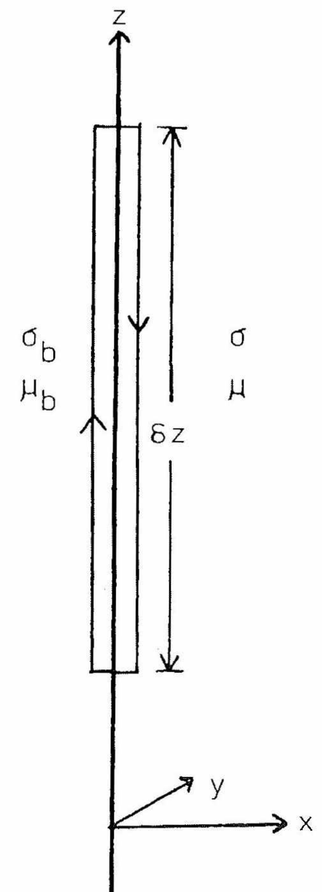

Fig 1: Geometry for an interface between two homogeneous conducting half-spaces of complex conductivies σ_b and s, and real magnetic permeabilities μ_b and μ.

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where J_x is the normal current density and $\tilde{n}$ is the (complex) interface impedance in ohms m^2. We now draw a rectangular circuit, in the plane $y = 0$, of length δz and infinitesimal width as indicated in Fig 1. Assuming H_y is bounded in the plane $x = 0$, we can say that the line integral, of the vector electric field **E** around the rectangular circuit of vanishing area, is zero. An equivalent statement is:

$$E_{bz}\delta z - E_z\delta z + \tilde{n} J_x(\delta z) - \tilde{n} J_x(0) = 0 \qquad (1)$$

But also

$$J_x(\delta z) = J_x(0) + \delta z[\partial J_x(\delta z)/\partial \delta z]_{\delta z=0} + \ldots \qquad (2)$$

Thus in the ultimate limit $\delta z \to 0$, for any z:

$$E_{bz} - E_z = -\tilde{n}\partial J_x / \partial z \qquad (3)$$

which relates the discontinuity of the tangential electric field, at the interface $x = 0$, to the tangential gradient of the normal current density. This relation holds for any frequency but in the static limit (ie $\omega \to 0$), we can write

$$E_{bz} = -\partial\phi_b / \partial z \text{ and } E_z = -\partial\phi / \partial z$$

where ϕ_b and ϕ are the respective potentials on the two sides of the interface. Then (3) reduces to the expected form

$$\phi_b - \phi = \tilde{n} J_x (\text{at } x = 0) \qquad (4)$$

Of course, it also follows that, for any frequency:

$$E_{by} - E_y = -\tilde{n}\partial J_x / \partial y \quad (\text{at } x = 0) \qquad (5)$$

and, again, (4) is recovered in the static limit. Here we might note, while J_x is continuous, E_x is not. That is

$$\sigma_b E_{bx}(at\ x = -0) = \sigma E_x(at\ x = +0) \qquad (6)$$

Now the other case of interest is when the interface between the half-spaces is replaced by a thin conducting sheet of conductance g. This parameter can be defined as the product of the sheet conductivity σ_s and the sheet thickness d. To be explicit we write

$$g = \sigma_s d \text{ in the limit } \sigma_s \to \infty \text{ and } d \to 0.$$

The units for g are mhos or siemens. To be perfectly general we can regard g as a sheet admittance if σ_s is replaced by $\sigma_\varepsilon + j\omega e_\varepsilon$ where ε_ε is the permittivity of the sheet material. But we will neglect any displacement currents within the sheet and thus g is real.

With reference again to the geometry shown in Fig 1, we can apply Ampere's Law to the same rectangular circuit. That is, we integrate the vector magnetic field around the rectangle, in the clockwise direction, which is then equated to the total current I_y in the y direction. It then follows that

$$H_{bz} - H_z = gE_{by} \quad (\text{or} = gE_y) \qquad (9)$$

which relates the discontinuity of the tangential magnetic field to the tangential electric field within the sheet. In this limit $E_{by} = E_y$ which actually is a good approximation, to a conducting sheet of finite thickness d, if $|\gamma d| << 1$ where γ is the complex propagation constant of the sheet material for an angular frequency ω (ie, the sheet is electrically thin). This limitation was discussed in a quantitative manner by Aguirre and Wait [6] in a different context. In a similar manner we deduce, again for $x = 0$, that

$$H_{by} - H_y = -gE_{bx} \quad (\text{or} = -gE_x) \qquad (10)$$

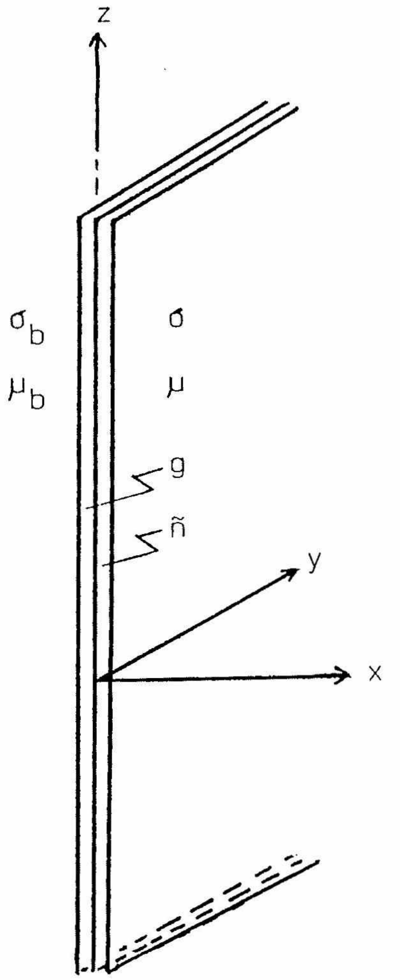

Fig 2: A composite or double layer between two homogeneous half-spaces.

We now deal with the composite double layer illustrated in Fig 2 where it is understood that the composite layer is unbounded in both the y and z directions. As visualised, the physical situation is that we have a thin conducting metal sheet, of conductance g, coated on one side by a highly resistive coating of interface impedance $\tilde{n}$. Thus *both* tangential E and H have an effective discontinuity between the two sides of the composite layer. (ie, at $x = -0$ and $x = +0$). The explicit boundary conditions are thus written:

$$H_{bz} - H_z = gE_{by} \quad (11)$$

$$H_{by} - H_y = -gE_{bz} \quad (12)$$

$$E_{bz} - E_z = -\tilde{n}\sigma\partial E_x / \partial z \quad (13)$$

$$E_{by} - E_y = \tilde{n}\sigma\partial / \partial y \quad (14)$$

Incident TM Plane Wave on Composite Thin Layer

In order to illustrate the application of these boundary conditions, let us consider the reflection and transmission of a TM (transverse magnetic) plane wave, at oblique incidence, from the region x > 0. The situation is shown in Fig 3.

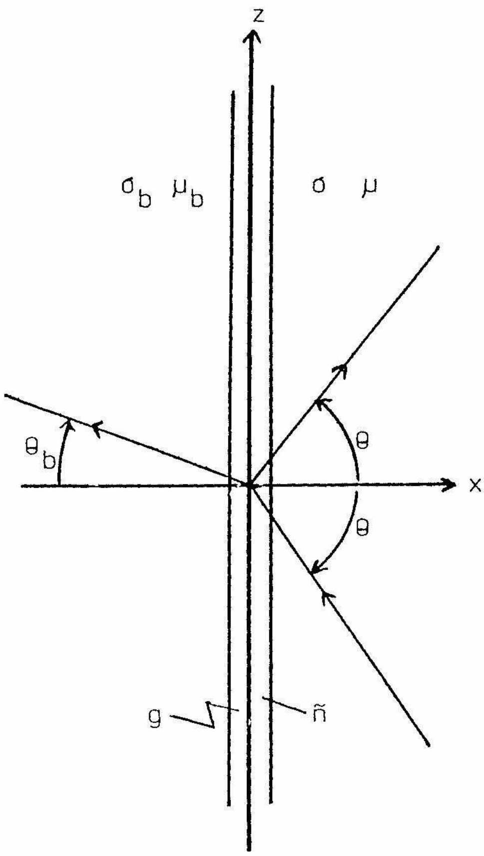

Fig 3: Plane wave incident at angle q from the region x > 0.

In this case the non-vanishing field components are E_x, E_z and H_y where we assume $\partial/\partial y = 0$. Then the relevant boundary conditions at $x = 0$ are

$$H_{by} = H_y - gE_{bz} \quad (15)$$

$$E_{bz} = E_z - \tilde{n}\sigma\partial E_x / \partial z \quad (16)$$

For $x < 0$, we may write

$$H_{by} = T\exp(-jpz)\exp(u_b x) \quad (17)$$

$$E_{bx} = -(1/\sigma_b)\partial H_{by} / \partial z = (jp/\sigma_b)H_{by} \quad (18)$$

$$E_{bz} = -(1/\sigma_b)\partial H_{by} / \partial x = (u_b / \sigma_b)H_{by} \quad (19)$$

where T is a transmission coefficient, $u_b = (p^2 + \gamma_b^2)^{1/2}$, $\gamma_b = (j\sigma_b\mu_b\omega)^{1/2}$ and p is the wave number in the z direction. For an angle of incidence θ, for the incoming plane wave in the region $x > 0$, we must have $jp = \gamma\sin\theta$ which is a fixed parameter where $\gamma = (j\sigma\mu\omega)^{1/2}$. The two half space regions, for $x < 0$ and for $x > 0$, are assumed to have real magnetic permeabilities equal to μ_b and μ, respectively. But the (complex) conductivities σ_b and σ are not restricted.

In accord with Snell's Law, we also note that $jp = \gamma_b \sin\theta_b$ where θ_b is the complex angle of transmission in the region $x < 0$. In view of Snell's equality $\gamma_b\sin\theta_b = \gamma\sin\theta$, the angle θ_b can be complex even when θ is real.

For the region $x > 0$ we now write:

$$H_y = \exp(-jpz)[\exp(ux) + R\exp(-ux)] \quad (20)$$

$$E_x = -(1/\sigma)\partial H_y / \partial z = (jp/\sigma)H_y \quad (21)$$

$$E_z = -(1/\sigma)\partial H_y / \partial x = \exp(-jpz)\,[\exp(ux) - R\exp(-ux)] \quad (22)$$

where R is a reflection coefficient and $u = (p^2 + \gamma^2)^{1/2}$.

On applying (15) and (16), we readily deduce that

$$R = \frac{[(u/\sigma) - p^2\tilde{n}][1 + (gu_b/\sigma_b)] - (u_b/\sigma_b)}{[(u/\sigma) + p^2\tilde{n}][1 + (gu_b/\sigma_b)] + (u_b/\sigma_b)} \quad (23)$$

and

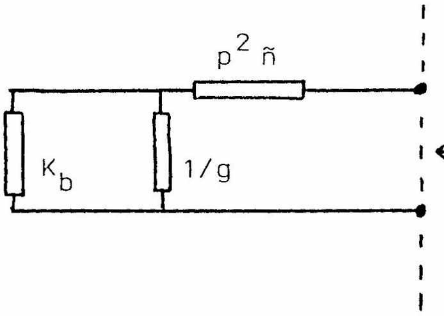

Fig 4: Equivalent circuit for a thin composite layer terminated by a homogeneous half-space for TM wave incidence.

$$T = \frac{2u/\sigma}{[(u/\sigma)+p^2\tilde{n}][1+(gu_b/\sigma_b)]+(u_b/\sigma_b)} \qquad (24)$$

It is useful to note that the reflection coefficient, as given by (23), can be written in the form

$$R = (K-Z)/(K+Z) \qquad (26)$$

where $K = u/\sigma$ is the wave impedence for the region $x > 0$. Also we note that

$$Z = p^2\tilde{n} + K_b(1+gK_b)^{-1}$$

is the input impedance at the interface $x = +0$ (ie at the incident wave side of the composite thin layer) and where $K_b = u_b/\sigma_b$ is the wave impedance in the backing region $x < 0$. The equivalent circuit corresponding to (26) is shown in Fig 4 where the elements are impedances each with dimensions of ohms. We observe here that the series element is proportional to $\sin^2\theta$ so it vanishes at normal incidence. We also note that, if the highly resistive or semi-insulating coating is absent, we set $p^2\tilde{n}$ in the equivalent circuit equal to zero. Then the input impedance is just the parallel combination of the medium impedance K_b and the impedance $1/g$ of the thin metallic layer.

Thin Composite Layer as the Limit of Two Slabs

To lend some credence to the derived thin layer formulae, we may deal directly with the problem without introducing the parameters at the outset. Thus, in place of the geometry shown in Fig 3, we adopt the more general version shown in Fig 5. The region x > 0 is again a homogeneous half space with (complex) conductivity and magnetic permeability μ. But now for the slab regions $0 > x - d'$ and $-d' > x > -(d'+d'')$, the (complex) conductivities and permeabilities are σ' and μ', and σ'' and μ'', respectively. The backing region, for $-x > d' + d''$, has a (complex) conductivity σ_b and a permeability μ_b.

For this double slab model of the transition region, we again consider that a TM plane wave be incident, from the region $x > 0$, at an angle of incidence θ. The solution for the reflection coefficient R, as it appears in (20) is known in exact form [11]. With the notation shown in Fig 5, we can express R in the form given by (25) but now $Z = E_z/H_y|_{x=+0}$ is the exact impedance and again $K = u/\sigma$ is the wave impedance within the region $x > 0$. To be explicit

$$Z = K'\frac{Z''+K'\tanh u'd'}{K'+Z''\tanh u'd'} \qquad (27)$$

where

$$Z'' = K''\frac{K_b+K''\tanh u''d''}{K''+K_b\tanh u''d''} \qquad (28)$$

where $K' = u'/\sigma'$, $K'' = u''/\sigma''$, and $K_b = u_b/\sigma_b$.

No approximations have been made here. But to examine the limit of the thin double layer shown in Fig 3, we consider the following limit process. First let $d'' \to 0$ and $|\sigma''| \to \infty$ such that the product $\sigma'' \times d'' = g$ is finite. Then clearly $u''d'' \to \gamma''d''$ and $K'' \to \gamma''/\sigma''$. At the same time we see that:

$$K''\tanh u''d'' \to (\gamma''/\sigma'')\gamma''d'' \to j\mu''\omega d''\sigma'' \to j\mu''\omega g \qquad (29)$$

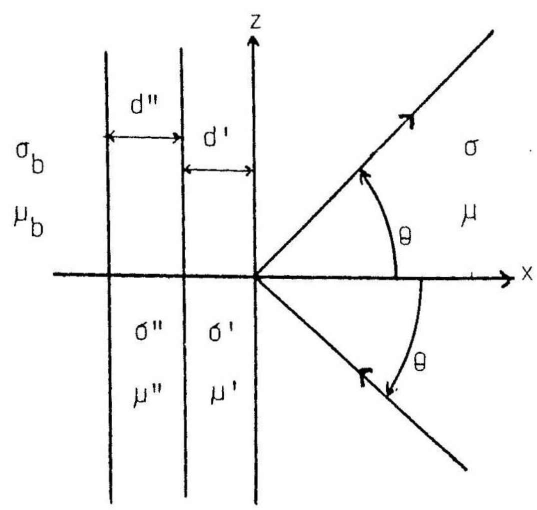

Fig 5: Two homogeneous slabs between two half spaces.

Thus, from (28) above,

$$Z'' \to (\gamma''/\sigma'')(u_b/\sigma_b)[(\gamma''/\sigma'')+(u_b/\sigma_b)\gamma'' d'']^{-1}$$

which simplifies to

$$Z'' \to 1/[(\sigma_b/u_b)+g] \qquad (29a)$$

As indicated, Z'' is the parallel combination of the sheet conductance g and the admittance σ_b/u_b of the backing medium.

Now we also let $d' \to 0$ but, in this case $|\sigma'| \to 0$ in such a manner that $d'/\sigma' = \tilde{n}$, the interface impedance, remains finite. Then also

$$K' = u'/\sigma' = (p^2 + j\sigma'\mu'\omega)^{1/2}/\sigma' \to p/\sigma'$$

and $\tanh u'd' \to u'd' \to pd'$. Then, from (27) above,

$$Z \to [Z''+p^2(d'/\sigma')]/[1+Z''\sigma' d'] \to Z''+\tilde{n}p^2 \qquad (30)$$

Using these limiting values and the reflection coefficient expression given by (25), we recover the previously derived (23). The same limit process can be used to obtain the transmission coefficient T as given by (24).

Incident TE plane wave on composite thin layer

In the examples discussed above, we assumed that the incident TM plane wave was polarised such that the magnetic field was oriented in the y direction. The other case of interest is when the electric field is oriented in the y direction. For this TE (transverse electric) configuration, the electric field, for the region $x > 0$, can be expressed in the form

$$E_y = \exp(-jpz)[\exp(ux) + R^* \exp(-ux)] \qquad (31)$$

which is analogous to (20) above. Here R^* is the corresponding TE reflection coefficient. For the same geometry as shown in Fig 2 for the composite sheet, the boundary conditions, at $x = 0$, are now simply

$$E_{by} = E_y \qquad (32)$$

and

$$H_{bz} = H_z + gE_y \qquad (33)$$

For the region, $x < 0$, we write

$$E_y = T^* \exp(-jpz)\exp(u_b x) \qquad (34)$$

being analogous to (17) above for the TM case.

It is a very simple matter to show that R^* in (31) is

$$R^* = \frac{[u/(j\mu w)] - [g + ((u_b/j\mu_b w))]}{[u/(j\mu w)] - [g + ((u_b/j\mu_b w))]} \qquad (35)$$

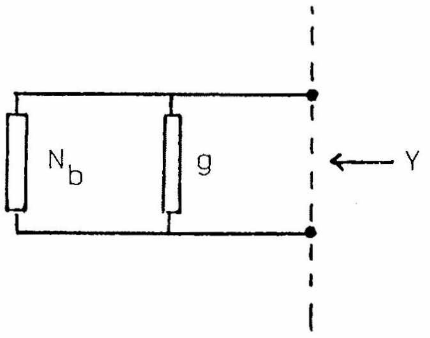

Fig 6: Equivalent circuit for a thin composite layer terminated by a homogeneous half space for TE wave incidence.

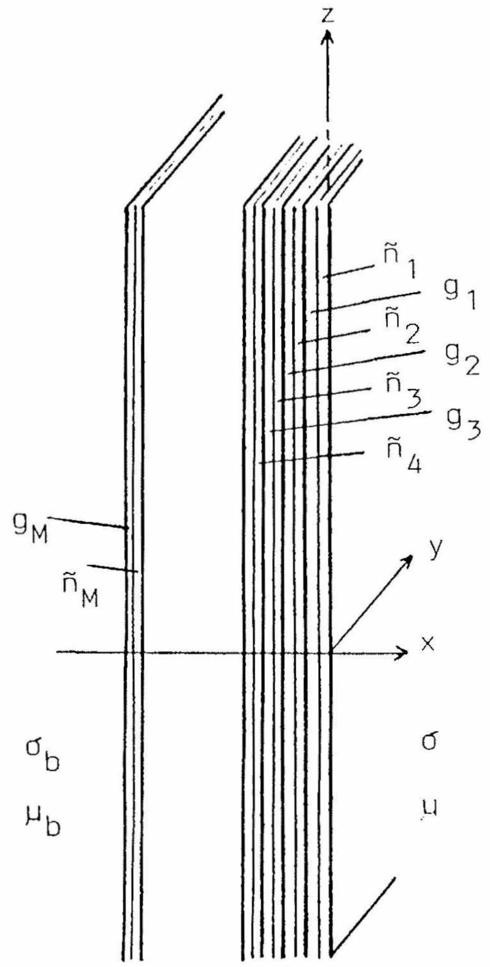

Fig 7: (not to scale) A general thin laminated planar structure separating two homogeneous half-spaces.

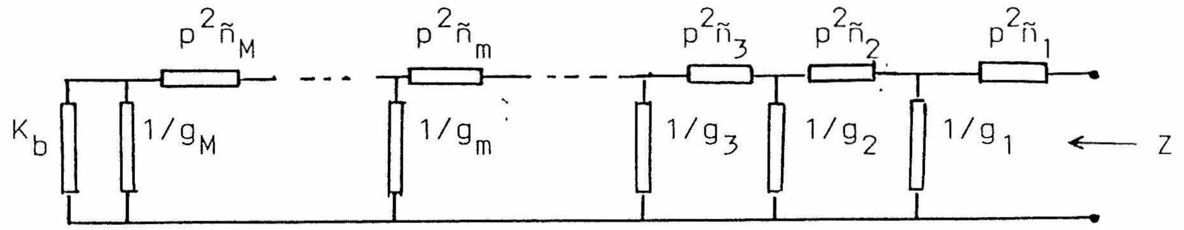

Fig 8: Equivalent circuit for the input impedance Z (at x = +0) for the structure shown in Fig 7 for TM plane wave incidence.

Then T^*, in (34) is

$$T^* = 1 + R^* \quad (36)$$

As before $u = (p^2 + \gamma^2)^{\frac{1}{2}}$ and $u_b = (p^2 + \gamma_b^2)^{\frac{1}{2}}$. We note here that the interface impedance $\tilde{n}$ does not show up in the expressions for R^* and T^*. Such is to be expected when the current flow is purely in the plane of the sheet.

Using the same argument as above for the TM case, it is easy to show that (35) also can be considered as the thin sheet limit of the exact expression for R^* of the double slab configuration shown in Fig 5. The equivalent circuit is obtained by noting (35) is equivalent to

$$R^* = (N - Y)/(N + Y) \quad (37)$$

where $N = u/(j\mu\omega)$ is the wave admittance for the region x > 0. Thus y is the input admittance at the interface x = +0 and it is given very simply by

$$Y = N_b + g \quad (38)$$

which is the sum of the sheet conductance g and the wave admittance $N_b = u_b / (ju_b\omega)$ of the backing region x < 0. The equivalent circuit, involving admittance elements, for this case is shown in Fig 6.

Thin Planar Laminated Structure

To generalise some of the above results, to a laminated structure of total small thickness, is a simple matter if the individual composite layers satisfy the thin sheet conditions. Thus we consider the model shown in Fig 7. We now have M individual composite layers. For the mth layer (where m = 1,2,3,...M) the conductance is and the interface impedance is $\tilde{n}_m$. Of interest here are the TM and TE reflection coefficients which again take the forms given by (25) and (37), respectively. Without belabouring the issue, we immediately show, in Fig 8, the form of the equivalent circuit which yields the appropriate impedance Z, for the TM case, at the interface $x = +0$. For any finite value of M, an algebraic expression for Z can be written down in the form of a continued fraction. For example if M = 3, we have

$$Z = p^2\tilde{n}_1 + \cfrac{1}{g_1 + \cfrac{1}{p^2\tilde{n}_2 + \cfrac{1}{g_2 + \cfrac{1}{p^2\tilde{n}_3 + \cfrac{1}{g_3 + K_b^{-1}}}}}} \quad (39)$$

where $K_b^{-1} = \sigma_b / u_b$.

In the limiting case of normal incidence (ie $\partial / \partial z = 0$ or $p = 0$), we see that $K_b = (j\mu_b w / \sigma_b)^{\frac{1}{2}} = ju_b w / \gamma_b$ and then

$$Z = [g_1 + g_2 + g_3 + \gamma_b / (j\mu_b\omega)]^{-1} \quad (40)$$

In this situation, the electric field is always parallel to the laminations so the thin highly resistive or insulating spaces between the conducting sheets play no role.

The general case for TE oblique incidence is actually very simple. The corresponding equivalent circuit is shown in

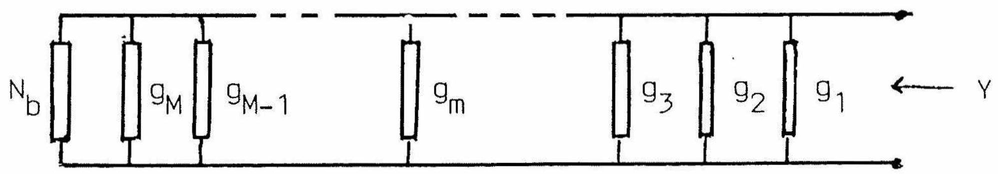

Fig 9: Equivalent circuit for the input admittance Y (at x = +0) for the structure shown in Fig 7 for TE plane wave incidence.

Fig 9. The input admittance, at $x = +0$, for any incidence, is now just the parallel combination of the conducting sheet conductances and the terminating admittance N_b where $N_b = u_b / j\mu_b\omega)$. Thus, for $M = 3$, we can write

$$Y = g_1 + g_2 + g_3 + N_b \quad (41)$$

As we would expect Z and Y are reciprocals in the case of normal incidence (ie where $p = 0$).

Final Remarks

While the thin composite or laminated models are highly idealised, various generalisations are easily carried out. For example, the assumed plane wave incidence can be the basis for arbitrary source excitation by employing the angular spectrum procedure [11]. Such a complex infinite integral representation incorporates both the TM and TE plane wave results discussed above. The transient or pulse response of the laminated model would also be of interest particularly in the context of geophysical studies where the buried target may be such a sheet-like structure. In such cases the thin resistive or semi-insulating films can represent electrochemical double layers [10]. Further investigations of this subject are continuing.

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The editors thank the referees for their assistance in evaluating this paper

A correction

James R Wait's article Basic Radiation Fields in the December 1993 issue of *The Radioscientist* contained a couple of errors:

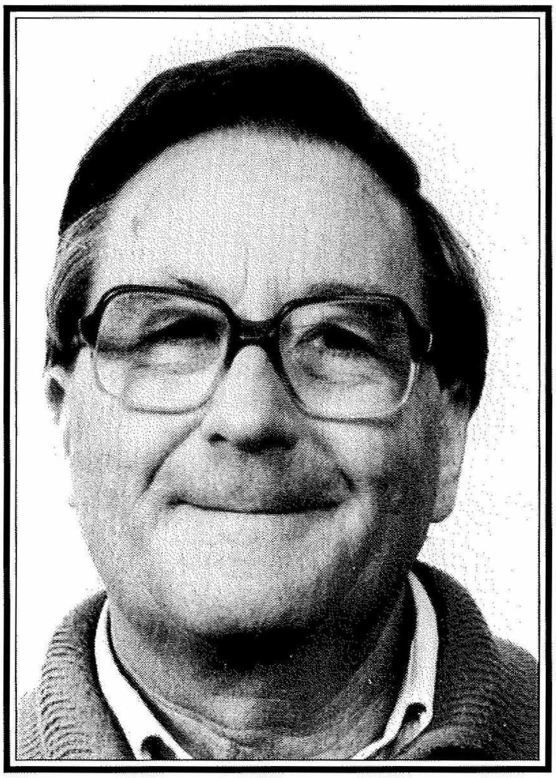
- Equation (20) on p 91 should read:

$$H_\phi = \frac{Il}{4\pi^2}(1 + i\beta r)e^{-i\beta r}\sin\theta \quad (20)$$

- The reference given in the footnote on p 92 should have dated Heinrich Hertz's article in *Wiedmanns Ann* as 1889, not 1989!

KEN BULLOUGH
1927-1994

Ken Bullough died on 10. March 1994. He was 66 years of age and in good health until he suffered a stroke, at the beginning of March, from which he did not recover.



Ken was born in Lancashire in 1927 and studied physics at Manchester University before going on to make radar studies of meteors at Jodrell Bank (1951 to 1955). He completed an MSc and then worked in Paris at the Laboratories of the Ecole Normale Superieure on the development and construction of radar equipment to study the aurora. He joined the French Expedition to Terre Adelie, Antarctica for the International Geophysical Year in 1957 and later earned his doctorate from the University of Paris. He became well known for VLF radio studies in Antarctica and on rockets and satellites. He was a frequent participant at URSI General Assemblies and contributed research papers even at some he was unable to attend. He was also a member of the URSI/IAGA Joint Working Group on Passive Electromagnetic Probing of the Magnetosphere.

Ken's scientific work can be divided into three parts:

1951- 1959: Radar studies, of meteors at Jodrell bank, and of the aurora with the French in Antarctica.

1960-1983: Rocket and satellite research at the University of Sheffield into VLF radio phenomena

1983-1994: He took early retirement in 1983 but continued to work on VLF phenomena for the rest of his life but became more and more interested in peace studies and published a number of papers in that area.

At Sheffield, Ken was responsible for designing rocket payloads which were launched from Woomera, Kiruna and South Uist and for VLF experiments flown on the Ariel 3 and Ariel 4 satellites. The Ariel 3 experiment was a particularly interesting project as the satellite was the first to be built in Britain and problems of electromagnetic compatibility which created enormous difficulty had to be solved. Both these experiments produced global maps of VLF activity which immediately suggested to Ken that electric power line harmonics must play an important part in the generation of VLF noise. He, with his student Adrian Tatnall, discovered a zone of permanent VLF emission activity over North America and its conjugate region and, controversially, ascribed these to high harmonics of 60 Hz radiated from power transmission lines. The subject of Power Line Harmonic Radiation subsequently become less fashionable but Ken continued to work on it, and noted hot-spots of VLF emission activity in the Ariel data which he associated with industrial point-sources such as cement works in Canada. He also suggested a link between secular changes in the weather — specifically an increase in thunderstorm activity — and VLF radio emissions stimulated by increased electrical power usage. Shortly before his death, Ken wrote a review article on the subject, to be published in the *Handbook of Atmospherics*.

Ken was also responsible for developing VLF direction-finding at a time when other research had suggested reliable results would not be obtained. He realised the importance of making ground-based observations of VLF noise to complement satellite measurements and established a VLF direction-finding experiment at Halley, Antarctica.

Throughout his working life Ken worked with many people to produce about seventy papers and articles but his most enduring working relationship and friendship was with Tom Kaiser with whom he worked at Jodrell Bank and later proposed many VLF radio experiments at Sheffield. Ken and Tom in addition to working together in the Sheffield Space Physics group worked as consultants for British Aircraft Corporation and advised on a number of European space projects.

Ken had a deep concern for the social consequences of the work of scientists, and this led him into the field of Peace Studies and Conflict Research, in which he published some original and well-respected contributions on the technical and scientific aspects of how to reduce the risk of nuclear war. He was also concerned with the plight of scientists in some countries who were suffering for their political or religious beliefs. He corresponded for many years with Sergei Sazhin , who was experiencing such difficulties in Russia, and campaigned for him to be allowed to leave the country. After many years Sergei was allowed to leave Russia and Ken was instrumental in arranging for him to come to work in Sheffield. It was in collaboration with Sazhin that Ken did much of his most recent work, after taking early retirement from the University. At a memorial service for Ken, Sergei described their relationship as that "of friendship between a capitalist from a socialist country with a socialist in a capitalist one".

Ken was never content with the conventional wisdom, and tenaciously argued the case for some of his unconventional views, which were acquired from a thorough examination and interpretation of the data. At the time of his death he was working on the hypothesis of "anti-matter comets". Many of us will remember debating with him, over coffee in Sheffield, his latest ideas, expressed in a characteristic Lancashire accent which he never lost in spite of many years residence in Yorkshire.

As well as a dedicated, original and concerned scientist Ken Bullough was a warm-hearted colleague and a committed family man. He leaves his wife Sonia, a son and two daughters.

Arthur Hughes and A J Smith

British Antarctic Survey, Cambridge, England

REVIEWS

Radiowave Propagation Over Ground

T S M Maclean and Z Wu, Chapman and Hall, London, 1993, ix + 299 pages, £ [GBP] 50.00, ISBN 0 412 42730 3.

This book by Maclean and Wu covers a rather narrow topic although the applied mathematical content and numerical techniques have relevance to other fields. The task, set forth by the authors, is to provide a self-contained deterministic theory of radiowave transmission over both flat and spherical models of the earth with all atmospheric effects discarded. Finite ground conductivity is accounted for and lateral discontinuities in the earth's electrical properties and terrain obstacles are also treated. Many numerical results of field strength vs range are given in graphical form, for specific cases, rather than in parametric form.

The principal contents of the book are as follows : Chapter 1 covers electromagnetic fundamentals including a brief introduction to the Leontovich boundary condition. In this same chapter, the Electromagnetic Compensation Theorem is described in a clear manner. The so-called vector form of this theorem is also mentioned but it is really equivalent to the original development by Monteath which deals with the mutual impedance of dipoles at the two ends of the path. In any case, the authors set the scene here for what follows.

In Chapter 2, the complete fields of electric and magnetic dipoles, located over a perfectly conducting ground plane, are presented. The corresponding radiated powers are also derived in a straight-forward fashion. In this case, of course, the input power to the transmitting dipole is the same as the radiated power. The material in this chapter can be found in standard antenna texts (which are now numerous indeed) but the authors' presentation is quite attractive.

In chapter 3, the well known Sommerfeld problem of dipoles over a homogeneous conducting half-space is outlined. Simplification is achieved by employing the surface impedance concept. Also, as pointed out some time ago by this reviewer (*AP-S Trans, 1,* p 9, 1953; *7,* 5-154, 1959.

Chapter 4 introduces the reader to mixed-path ground wave theory. The full blown Compensation Theorem formulation is used and compared with the earlier simpler forms based on Green's (scalar) theorem. The latter would not predict the form of the reflected wave at, for example, a coast-line. Here the authors might have devoted some attention to radial-wire ground systems which are needed in engineering of low frequency antennas to properly launch the radiowaves over the ground. The reader can refer to the cited references in this chapter (eg Chapter 23 in *Antenna Theory*, edited by Collin and Sucker, 1969).

Chapter 5 deals with numerous idealised eminently useful models for predicting the influence of irregular terrain such as cliffs, plateaus, and narrow ridges. The relevant integral equations are developed in a comprehensive fashion and the numerical procedures needed are explained clearly. The confirming scale model experiments are pretty convincing.

Chapters 6 and 7 cover the extension of the flat earth formulations to spherical (airless!) earth geometry. This topic has a rich history going back to the early theoretical studies by Poincaré, Watson (of Bessel function fame), Rayleigh (famous for almost everything), van der Pol (the Master), and Bremmer (his eminent protege) not to mention the prolific Soviets from the forties and fifties (eg Fock, Leontovich, Wvendensky, and Feinberg).

Chapter 8 presents general results for idealised terrain obstacles and mixed paths for a finitely conducting spherical (and again airless) earth. The equivalence with earlier modematching techniques, employed by other workers, is pointed out but no detailed comparisons are made. The cited references here to related studies will help the reader fill in the gaps and aid physical understanding the physics.

The price of the book is not unreasonable and libraries need to secure it. There is a companion software package (at £175) available from the publisher. It is not reviewed here.

James R Wait

Review editor
2210 East Waverly, Tucson, AZ 85719-3848, USA

Wave Propagation in the Ionosphere

Karl Rawer, Kluwer Academic Publishers, Dordrecht, Boston, London ISBN 0-7923-0775-5, 1993, US$175.00, 486 pages, hard cover.

This extensive book covers almost all modern aspects of the subject described in its title. Written by one of the world known experts in the field it can be used as a guide for physicists or electrical engineers beginning to specialise in ionospheric research, and also as a reference book for experts in the topic. Although the main emphasis is aimed at the theoretical aspects of wave propagation, the relevant experimental techniques are sufficiently described.

In Part A the fundamental properties of electromagnetic wave propagation in a stratified incompressible (= cold) magnetoplasma are treated. The eigenvalues of the conductivity tensor are calculated using an effective collision frequency as friction coefficient in the equations of motion for the charge carriers. The dispersion equation and the relations for the two characteristic polarisations are calculated and discussed with applications to echo sounding (ionograms) and whistler propagation.

The first two chapters of part B are devoted to the propagation of low frequency waves in the Earth-ionosphere waveguide, while the next chapter deals with the propagation through the ionosphere. The last two chapters describe irregularities, mostly caused by acoustic-gravity waves, whose basic equations are derived and discussed.

Part C starts with the introduction of kinetic theory to describe more rigorously the collision frequencies appearing in the conductivity tensor. In the third chapter the compressibility of the (warm) plasma is taken into account in the kinetic theory and the calculation of the conductivity tensor. The last chapters deal with the corresponding dispersion equation and relations for the three characteristic polarisations.

In part D various types of non-linear phenomena are treated in detail. Instabilities, mode coupling, incoherent scatter, particle precipitation, artificial and natural heating are the most important ones.

In six appendices the theoretical tools used in the main part of the book are introduced and explained in necessary detail.

The regrettably short bibliography lists mainly books and review articles but only very few journal papers.

Rawer's book is a most important publication in the ionospheric literature; the printing errors do not diminish its value as a standard book in a field interesting for plasma physicists, radio engineers and geophysicists.

Kurt Suchy

Institut für Theoretische Physik II, Heinrich-Heine-Universität, Düsseldorf, Germany

The Division Bell

Pink Floyd, Columbia 476581-2 (CD), Sony Music Entertainment Inc, 1994.

Natural sounds — birds, whales, wind — have long been featured by record artists. This music album will interest radioscientists and engineers for its use of what are called "Earth noises" in the opening track. Here at Otago we analysed these through our in-house DSP and spectrographic software GRAFT, revealing the VLF hiss and sferics as having been cleverly filtered, presumably to avoid damage to Floyd fans' hi fi equipment! "Earth noises" is credited to G William Forgey, not found in our scientific abstract databases, so 'unavailable for comment'.

Douglas Adams and Stephen Hawking are credited too: Professor Hawking narrates some of the lyrics in track 9 "Keep Talking" — this could be some sort of cruelty, as his 41 words must have required extreme effort.

Those who recall the "bacon and eggs" sound effects of "Adam's Psychedelic Breakfast" from Pink Floyd's 60s period will note with irony the similarity to the latest crackle and hissing, but you'll find the music has become rather insipid since their mid-80s split turned the band into just a "brand".

Peter Dowden

Production editor

The Canadian Advanced Digital Ionosonde (CADI)

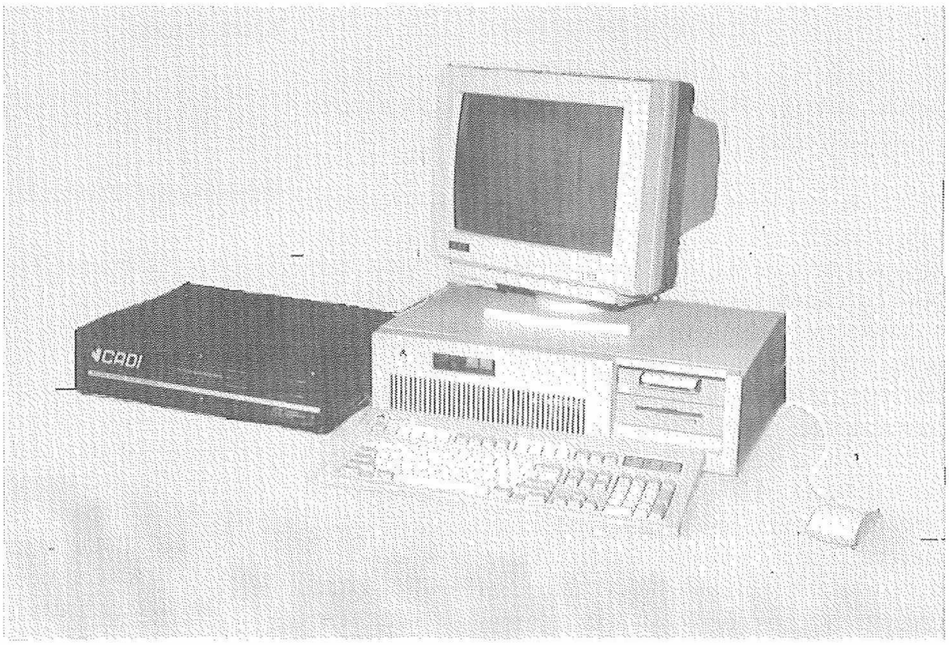
Scientific Instrumentation Limited (SIL)

Saskatotoon, Canada

Product information

The Canadian Advanced Digital Ionosonde (CADI) is a state of the art, low cost, full featured ionosonde ideal for both routine ionospheric monitoring and scientific research.

CADI provides sounding capability using high-power radio frequency pulses at vertical incidence. The system integrates phase coding techniques, solid state electronics and PC technology to make CADI a significantly smaller and less expensive ionosonde. The system may be operated with single or multiple receivers. Observables include: echo delay (height) versus frequency; the phase and amplitude of the echo; angle of arrival; and polarisation of the echo. Drifts can also be measured using the spaced-antenna method. This information is used in radio propagation forecasts of the most effective operating frequency for point to point radio communication. The data is also used in scientific research relating to the ionosphere.



SIL's Canadian Advanced Digital Ionosonde: here shown next to a PC

Features

- Height range up to 512 km (to be increased to 1000 km) with 6 km resolution.
- The digital control system provides high flexibility. Multiple operating modes are available.
- Frequency range from 1 to 20 MHz. Three standard sweeps are provided: low resolution (100 frequencies), medium resolution (200 frequencies), high resolution (400 frequencies). The step size may be selected to be linear or logarithmic.
- System is PC-based with the major units of the ionosonde mounted on plug-in boards. A basic one-receiver system uses two plug-in boards.

Transmitter

The transmitter power required is only 600W. Amplifier units are all solid state and include monitors for forward and reverse power. The use of pulse coding techniques gives an 11 dB signal to noise (S/N) ratio improvement, equivalent to having about thirteen times the transmitter power.

Receiver

The system can incorporate four or more receivers for spaced antenna measurements. The receiver outputs are sampled simultaneously using two microprocessors per channel. The increased data rate over a time-shared antenna system allows further improvements to the S/N ratio using post-detection processing.

Frequency Synthesiser

Frequency generation is provided by a frequency synthesiser based on direct digital synthesis (DDS). The synthesiser has two channels and can produce two output frequencies that can be changed almost instantaneously in frequency or phase. The DDS synthesiser provides the transmitter frequency and the receiver local oscillator frequency.

Noise Suppression

Coherent pulse averaging is used to further improve the S/N. In practice, four pulse averages (at medium resolution) are used, giving a 6 dB S/N improvement. Longer averages tend to obscure real changes in the ionosphere. If the data is processed in a 'spectral' mode, longer averages are possible. This is usually done only for selected data.

Post processing using Fast Fourier Transforms (FFTs) is being evaluated as an alternative. The sample length would no longer be limited; cancellation is avoided as the phase difference between pulses becomes a frequency shift. For a 64 pulse sample FFT, the S/N improvement is 18 dB over a single pulse sample. The use of FFTs on a modern PC offers tremendous benefits without a large delay (a few minutes per ionogram) or expensive special processors.

Operation

The operating software provides a menu of operating modes from which the operator makes a selection.

A complete ionogram requires from a few seconds (at low-frequency resolution and averaging two pulses) to several minutes (at high resolution averaging 16 pulses). A medium-resolution ionogram with four pulse averaging requires about 45 seconds.

Data is stored to the computer's hard disk. The data is periodically backed up to 120 MB tape cartridges using a standard Colorado Memory Systems backup unit. Remote control and communication is possible using standard PC communication packages.

APPLICATIONS

CADI is operated as a vertical incidence sounder (VIS) providing information on the state of the local ionosphere. CADI provides direct information on the echo delay (virtual height) as a function of frequency, the phase and amplitude of the reflected signal and the doppler shift due to motion of the reflector, at one or a series of frequencies. With multiple receivers the angle of arrival may also be determined from the phase delay at different receivers. From this information the electron density profile and the drift field may be derived.

Software

Data collection and analysis software was developed in close collaboration with researchers at the University of Western Ontario. Scaling software is provided to allow manual scaling of the standard URSI parameters. Advanced analysis software may be obtained on agreement between SIL and UWO. This package utilises Interactive Data Language (IDL®) routines and has not yet been integrated in the commercial package.

The CADI Network

The CADI system has already become an integral part of the Canadian Network for Space Research program, one of Canada's Networks of Centres of Excellence. Extensive collaboration among the space and atmospheric research community is providing in-depth and effective use of data from the sounders now operating. Links have also been established with the Canadian military and the Department of Communications.

The following sites are presently in operation:

- Rabbit Lake, Sask (58°N, 106°W)
- Resolute Bay, NWT (75°N, 95°W)
- Eureka, NWT (80°N, 84°W)
- Cambridge Bay, NWT (69°N, 105°W)
- London, Ont (test site)

Planned locations include Saskatoon, Sask (52°N, 107°W); Alert, NWT (82°N, 63°W); HIPAS, Alaska.

Usage

CADI is a full-featured digital ionosonde with a broad range of applications. The combination of portability, low cost and ease of installation make CADI ideal for both permanent installations and campaign-type research programs of shorter duration.

The potential application of the CADI sounder to atmospheric research is quite large. A short list of current applications includes

- polar cap studies, including morphology and behaviour of patches and arcs
- auroral zone studies, stand-alone and in conjunction with optical and VHF/HF radar measurements
- studies relating ionospheric effects to wind, wave and tidal measurements in the mesosphere
- equatorial and high latitude electrojet studies.
- ionospheric monitoring: CADI provides the full complement of basic information on the state of the ionosphere required for routine monitoring.
- scaling of standard URSI parameters
- data storage format suitable for World Data Centre archives.

For communications applications, CADI provides the following capabilities:

- frequency management based on state of local ionosphere
- diagnostic sounding, suitable for interpreting the known statistical behaviour of various ionospheric parameters

- cooperative check target for an HFDF system

Future Development

The development of the CADI system is an ongoing process. SIL and researchers at the UWO are involved in the joint development of additional features which will enhance the capabilities of the sounder. Our commitment is to the further development of CADI as a an accessible, low cost, flexible full-featured instrument with a broad range of uses in scientific and communications research and monitoring of the ionosphere.

Further reading

S Gao & J MacDougall. A dynamic ionosonde design using pulse coding. *Can J Phys 68*, 1184 (1991)

For further information please contact:

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Canada

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SPAN: cansas::sil
Internet: sil@skisas.usask.ca

Specifications

Pulse Power:	600 W
Frequency Range:	1 to 20 MHz
Frequency Sweeps:	100, 200, 400 linear or logarithmic steps
Frequency Generation:	DDS-based synthesiser
Height Range:	90 to 512 km
Height Resolution:	6 km
Pulse Coding:	13 bit Barker or single pulse
Storage:	Standard 120 MB tape backups
Power Requirements:	PC plug-in boards run off standard bus power. Power amplifier units require 110/220 V, 50/60 Hz, 100 VA
Dimensions:	Power amplifier cabinet 10 x 12 x 8"
Computer:	IBM compatible PC with at least two free 8 bit slots (5 slots for a four-receiver system)
Graphics:	CGA for single receiver EGA/VGA for multiple receivers

Teletext without TV in Russia

E Kharybin*, A Feldstein†, L Gendelev*, S Munin*

* *National Information Agency [Russia]; †Geophysical Centre, Russian Academy of Sciences*

The National Information Agency (NIA) of Moscow, Russia, has introduced a new data service having some similarities to both Teletext and the Internet services but without using TV receivers or connection to a computer network. Like Teletext, digital data is broadcast between the picture frames but received directly on the recipient's computer via a plug-in TV receiver board. This means that, unlike Teletext, huge amounts of data (even gigabytes) can be recorded on hard disks or optical disks, and is accessible to sophisticated processing software. Like the Internet services, one can choose the topics in advance, but since no line connection is required, the NIA service can be available in remote and sparsely populated areas where such lines may never be available. At present, broadcasting is run through the local TV channel and can be received only in Moscow and in Moscow region . In the near future it is planned to shift broadcasting to the main Russian TV channel which uses communication satellite transmission. As a result, this NIA service is, in principle, available anywhere in the world.

1. Software

The software developed is based on a high-performance data-base management system, "Btrieve Record Manager" by Novell. It is named "Mkbase" and allows one to work with extremely large data bases. In the process of Mkbase designing the number of data types was minimised and eventually reduced to the following four: line, number, data and document.

The first three do not require comment. The "document" can be text, graphics, sound, processing routine, database, etc. Mkbase is a menu-driven many-windows system which is characterised by

- high speed search and data processing;
- implementation of sophisticated requests comprising numerous criteria. Moreover, requests are not restricted by index fields only;
- flexible customising for information arrays with inhomogeneous structure — input data can be presented in the form of text, tables, graphics, figures and sound.
- built in subsystems of graphical and statistical data processing;

- simultaneous work with several data bases;
- friendly interface;
- possible realisation using cheap, reliable hardware (IBM AT, 386, 486 or Pentium).

2. Broadcasting

Our TV is SECAM D/K type and works in the standard HF/ VHF TV range. Every frame contains 25 service lines, 8 of which are always blank, and there are 50 frames per second. Every service line contains from 16 to 45 bytes of information (naturally the more information squeezed into a line, the higher the probability of error in the process of broadcasting). The Teletext international standard is based on 45 bytes per line but the same information is broadcast many times in order to achieve a low enough error rate. But the internal structure of Teletext files makes it impossible to reach high reliability of data transmission even if using only 16 bytes per line.

The NIA system uses 16 bytes per line for low error rate, which is particularly important when the TV broadcasting is realised via a satellite, but owing to a new system of internal codes it does not require repetition of information broadcasting (as in Teletext) and the volume of *useful* information is 1.35 megabytes per hour per single line. This means about 11 megabytes per hour per channel if 8 blank lines are used. Thus the reliability of the broadcast information is around three orders of magnitude higher than for Teletext. It is possible also to use 45 bytes per line, which means an increase by 2.8 times in speed of data transmission, but this would decrease reliability.

Despite virtually global broadcasting of data, this NIA service none the less provides data security. In Teletext it is also possible to introduce a system of keys to limit information reception to specific clients, but this Teletext system can be circumvented without great difficulty. On the other hand, one will be unable to decipher a file broadcasted via NIA system without proper authorisation. Yet the standard NIA receiver allows reception of Teletext as well.

It is possible to receive 5 to 6 channels simultaneously and this number can be increased without problem — it simply depends on the characteristics of the computer in which the NIA reception card is installed.

3. Present data bases

Software developed in NIA allows incorporation of many different data arrays into the information medium and makes it possible for users to work with data bases consisting of some hundred thousand records. At present the following blocks are provided in the information medium structure:

- goods and raw materials (demand and supply at commodity exchanges, direct offers of output producers and consumers);
- prices (retail and wholesale, international and domestic);
- stocks (Russian stock exchanges quotations, credit auctions);
- currency (exchange rate of the rouble relative to main currencies, participants and volumes of currency auctions in Moscow);
- investments (investment funds, investment risks, credit resources in different Russian regions);
- banks (Russian banks, their statutory funds, lists of their unreliable clients);
- addresses (enterprises and firms, insurance companies, arbitrage court and tax offices in Moscow, wholesale storage);
- external economical relations (export-import transactions);
- statistics (goods and services, industry, social sphere);
- auxiliary (basic data about Russian regions, international and domestic phone codes, other communication facilities).

Basic suppliers of data to NIA are the Russian Committee for Statistics, the Russian Customs Committee, the main exchanges and other reliable sources. NIA data bases are continuously replenished at an averaged rate of about 700 megabytes per month and their full volume already exceeds 10 gigabytes. Information in Russian will be partially duplicated in English.

Besides regularly transmitted information, which is based on the general user's standard requests, NIA is also able to include in the broadcasting program *any* data array that one individually requests from the NIA archive.

Those interested in more detailed information can write:

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