The Radio Science Bulletin

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INTERNATIONAL UNION OF RADIO SCIENCE

UNION RADIO-SCIENTIFIQUE INTERNATIONALE

U.R.S.I.

2005 Awardees

Prof. I.V.I. Lindell

Prof. J.B. Andersen

Dr. D. Massonnet

Prof. Y. Rahmat-Samii

Prof. S.C. Hagness

No 313
June 2005

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Contents

Front cover: At the XXVIIIth URSI General Assembly in New Delhi (India), the scientists whose pictures feature on the front cover were presented with the URSI Awards. Fore more information, please turn to page 9 of this bulletin.

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

Editorial

June in December?

Yes, this is the June issue of the *Radio Science Bulletin*, and it's coming to you in December. This issue and the September and December issues of the *Bulletin* will be late, I'm afraid, and the responsibility is mine. I'm sorry. As one way of getting the *Bulletin* back on schedule, for the next few issues I will not be doing the same level of editing on the material we publish as I have been.

We have included in this issue material from the New Delhi General Assembly, and all of the normal end-of-the year listings of URSI radio scientists' contact information, which would usually go into the December issue. Hopefully, we'll be back on schedule by the spring.

The XXVIIIth URSI General Assembly

The XXVIIIth General Assembly of URSI in New Delhi, India, was a wonderful success. We had more than 1400 attendees, and the quality of the technical sessions and poster presentations was outstanding. Equally outstanding was the hospitality shown to all in attendance by our Indian hosts. As just one example, the banquet transformed the lawn and grounds of the National Physical Laboratory into a wonderland of lights; food booths, with something for every taste; wandering performers; handicraft booths; stage shows with puppets, live actors, acrobats, and dancers; and a pair of elephants giving rides at the entrance! The involvement of the President of India in the opening ceremony, presenting one of the General Lectures, and hosting a most elegant tea for the Young Scientists made the whole experience of the General Assembly even more special. Heartfelt thanks go to Dr. A. P. Mitra, Dr. V. Kumar, Dr. P. Banerjee, Dr. M. K. Goel, and all of their colleagues on the Local and National Organizing Committees, as well as their many colleagues at the National Physical Laboratory, for the years of effort that made all of this possible. Special thanks, too, go to Prof. Gert Brussaard, the Coordinator for the Scientific Program, who led the organization of the scientific program, and whose ability to adapt the organization to the changing needs of the General Assembly as it was happening made the whole experience so very excellent.

The Council voted to hold the XXIXth URSI General Assembly in Chicago, Illinois, August 9-16, 2008. Prof. George Uslenghi, incoming Chair of the US National Committee for URSI, is the Chair of the Organizing Committee, and will be the Associate Coordinator for the Scientific Program. Dr. M. K. Goel, of India, will be the Coordinator for the Scientific Program.

Special Section Honoring Carl E. Baum

This issue and the March issue of the *Radio Science Bulletin* contain special sections honoring Carl E. Baum on his 65th birthday. We have two guest Editors for these special sections, Jürgen Nitsch and Frank Sabath, and they have provided an excellent introduction to the special section, this time focusing on some of the more personal aspects of Carl Baum and his contributions outside of science and engineering.

What is "ultra-wideband?" This is the basic question one of our Guest Editors, Frank Sabath, and his coauthors, E. L. Mokole, and S. N. Samaddar, address in their paper. Ultra-wideband signals and systems have come into wide-spread usage in recent years. However, what constitutes an "ultra-wideband" signal or system varies from application to application, field to field, and even among emerging standards. The authors identify and explain the major definitions and usage of the term, and also explain the differences among these. They then suggest some further research and discussion that could lead to a common definition and a classification scheme that could be widely applicable.

Model-based parameter estimation is the process of fitting a model to a set of data, and determining the parameters of the model that best fit the data. A very simple example is the fitting of a polynomial curve to a two-dimensional plot of some data. The parameters involved are the coefficients of the polynomial. In the case of trying to identify scattering objects from radar data, it can be very useful to fit a model based on a sum of complex exponentials. There are several methods of doing this, and a comparison of three of these methods is the topic of the paper by Seongman Jang, Wonsuk Choi, Tapan Sarkar, and Eric Mokole. They consider the Matrix Pencil Method and two methods of retrieving harmonics using a state-space approach. They compare the ability of these three methods to accurately determine the poles of the models for five canonical electromagnetic scatterers. While the three methods perform similarly when the data are smooth, they produce different results when the data are not smooth, and when there is significant noise present. There are also significant differences in the computational requirements for the three methods.

Leland Bowen, Everett Farr, Dean Lawry, and Scott Tyo describe the design of a very compact impulse-radiating (ultra-wideband) antenna in their paper. The design is specifically intended for use on a low-Earth-orbit satellite. One of the interesting aspects of this paper is that it traces the development of the ultimate design for the antenna through three evolutions, with measured data and experience with the mechanical-design aspects being presented for each. The antenna uses a collapsible design, with a metallic-covered fabric forming the surface of the reflector. The descriptions of the development of the mechanism for deploying the antenna, as well as for supporting the reflector surface, provide interesting insight into what is necessary for space-based applications. The final resulting antenna achieved many of the design goals, and is capable of supporting either single- or dual-polarization operation.

Our *Reviews of Radio Science* papers will resume with the next issue of the *Bulletin*.

Best Wishes for the New Year!

This will reach our readers in December, or shortly after the new year. At the end of one year and the beginning of the next, there are many opportunities to reflect on what we have received in the year past. I'm thankful for the honor and fun of being able to work with all of the wonderful people associated with URSI, and particularly, with the *Bulletin*: Paul Lagasse, Inge Lievens, Inge Heleu, John Volakis, Phil Wilkinson, our Associate Editors, and the URSI Board (this time, both new and old). These people do a wonderful job, are very tolerant of an Editor's shortcomings, and are very professional. Thank you!

I wish all in the radio science community a most happy, healthy, safe, and prosperous New Year!

W. Ross Stone

Subscribe now !

If you were not able to attend the URSI General Assembly in New Delhi (India) last October, please fill in the form on the back cover of this issue and pay your Radioscientist fee as soon as possible with VISA or MASTERCARD, so that you will receive the Radio Science Bulletin in the next triennium also. Please note that we do not accept cheques.

URSI Accounts 2004

In 2004, a year preceding a General Assembly, the URSI balance already reflects some costs related to the General Assembly, such as the meeting of the Coordinating Committee. We also observe increased expenditures due to increased activities of the Commissions. The total expenditures were about 74 kEuros higher than in 2003. At the same time, the income was small, about 167 kEuros less than in 2003, mainly because in 2004 the member committees paid only 79% of their dues. This resulted in a deficit of about 63 kEuros. The Treasurer suggests to act upon Article 9 of the URSI Status and consider those member committees which do not pay their dues for more than 2 years as having resigned from the URSI and give them a possibility to apply for the Associate Membership of the Union.

In spite of the fact that the URSI assets shrunk compared to the previous year, partly due to the turmoil at the stock market and unfavourable US dollar-Euro exchange rate, the market value of our investments has increased by about 14 kEuros.

Nevertheless the URSI finances are sound and we are well prepared for GA 2005 in New Delhi.

Andrzej W. Wernik
Treasurer

BALANCE SHEET: 31 DECEMBER 2004

ASSETS	EURO	EURO
Dollars		
Merrill Lynch WCMA	3,169.09	
Fortis	4,162.71	
Smith Barney Shearson	67.78	
		7,399.58
Euros		
Banque Degroof	617.02	
Fortis	128,185.32	
		128,802.34
Investments		
Demeter Sicav Shares	17,187.24	
Rorento Units	84,425.18	
Aqua Sicav	48,333.83	
Merrill-Lynch Low Duration (305 units)	2,350.66	
Massachusetts Investor Fund	209,219.10	
	361,516.01	
684 Rorento units on behalf of van der Pol Fund	9,407.03	
		370,923.04
Short Term Deposito		50,832.14
Petty Cash		366.75
Total Assets		558,323.85
Less Creditors		
IUCAF	9,865.71	
ISES	9,889.28	
		(19,754.99)
Balthasar van der Pol Medal Fund		(9,407.03)
NET TOTAL OF URSI ASSETS		**529,161.83**

The net URSI Assets are represented by:	EURO	EURO
Closure of Secretariat		
Provision for Closure of Secretariat		90,480.00
Scientific Activities Fund		
Scientific Activities in 2004	32,045.00	
Publications in 2004	60,320.00	
Young Scientists in 2004	39,585.00	
Administration Fund in 2004	64,090.00	
I.C.S.U. Dues in 2004	6,032.00	
		202,072.00
XXVIII General Assembly 2005 Fund:		
During 2003-2004-2005		188,500.00
Total allocated URSI Assets		481,052.00
Unallocated Reserve Fund		48,109.83
		529,161.83

Statement of Income and expenditure for the year ended 31 December 2004

I. INCOME	EURO	EURO
Grant from ICSU Fund and US National		
Academy of Sciences	0.00	
Allocation from UNESCO to ISCU Grants Programme	0.00	
UNESCO Contracts	0.00	
Contributions from National Members	152,403.00	
Contributions from Other Members	0.00	
Special Contributions	0.00	
Contracts	0.00	
Sales of Publications, Royalties	0.00	
Sales of scientific materials	0.00	
Bank Interest	950.29	
Other Income	0.00	
Total Income		**153,353.29**

II. EXPENDITURE

A1) Scientific Activities		87,802.47
General Assembly 2005	27,720.19	
Scientific meetings: symposia/colloqiua	55,634.85	
Working groups/Training courses	0.00	
Representation at scientific meetings	4,447.43	
Data Gather/Processing	0.00	
Research Projects	0.00	
Grants to Individuals/Organisations	0.00	
Other	0.00	
Loss covered by UNESCO Contracts	0.00	

	EURO	EURO
A2) Routine Meetings		7,315.82
Bureau/Executive committee	7,315.82	
Other	0.00	
A3) Publications		29,159.62
B) Other Activities		7,530.23
Contribution to ICSU	3,530.23	
Contribution to other ICSU bodies	4,000.00	
Activities covered by UNESCO Contracts	0.00	
C) Administrative Expenses		85,029.71
Salaries, Related Charges	61,970.59	
General Office Expenses	13,126.00	
Office Equipment	3,129.57	
Accountancy/Audit Fees	5,006.38	
Bank Charges	1,797.17	
Loss on Investments	0.00	
Total Expenditure:		**216,837.85**

Excess of Income over Expenditure	(63,484.56)
Currency translation difference (USD => EURO) - Bank Accounts	(863.64)
Currency translation difference (USD => EURO) - Investments	(42,192.84)
Currency translation difference (USD => EURO) - others	66,325.73
Accumulated Balance at 1 January 2004	569,377.14
	529,161.83

Rates of exchange:

January 1, 2004	$ 1 = 0.8420 EUR
December 31, 2004	$ 1 = 0.7540 EUR

	EURO
Balthasar van der Pol Fund	
684 Rorento Shares: market value on December 31, 2004	
(Aquisition Value: USD 12.476,17)	27,277.92
Market Value of investments on December 31, 2004	
Demeter Sicav	57,145.44
Rorento Units (1)	518,440.00
Aqua-Sicav	79,094.21
M-L Low Duration	2,336.50
Massachusetts Investor Fund	163,524.80
	820,540.94

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

APPENDIX: Detail of Income and Expenditure

	EURO	EURO
I. INCOME		
Other Income		
Income General Assembly 2005	0.00	
		0.00
II . EXPENDITURE		
General Assembly 2005		
Organisation	27,720.19	
Vanderpol Medal	0.00	
Expenses officials	0.00	
Young scientists	0.00	
		27,720.19
Symposia/Colloquia/Working Groups:		
Commission A	2,824.97	
Commission B	9,000.00	
Commission C	6,000.00	
Commission D	6,500.00	
Commission E	5,299.88	
Commission F	1,750.00	
Commission G	3,500.00	
Commission H	3,000.00	
Commission J	9,000.00	
Commission K	7,260.00	
		55,634.85
Contribution to other ICSU bodies		
FAGS 2004	2,000.00	
IUCAF 2004	2,000.00	
		4,000.00
Publications:		
Printing ‘The Radio Science Bulletin’	12,281.66	
Mailing ‘The Radio Science Bulletin’	16,877.96	
		29,159.62

URSI AWARDS 2005

The URSI Board of Officers decided at their May 2005 meeting in Ghent to follow the recommendations of the Awards Panel and to give the 2005 Awards to the following distinguished scientists:

The Balthasar Van der Pol Gold Medal

The Balthasar Van der Pol Gold Medal was awarded to Prof. Ismo V.I. Lindell with the citation :

"For the development of new methods and solutions in electromagnetic field theory and for exceptional skills."

John Howard Dellinger Gold Medal

The John Howard Dellinger Gold Medal was awarded to Prof. Jorgen B. Andersen with the citation:

"For significant contributions to the theory of antenna characteristics and scattering, wave propagation and inhomogeneous areas in mobile communication, and interaction between electromagnetic field and biological tissue."

Appleton Prize

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

The Council of the Royal Society approved the recommendation of the URSI Board to award the 2005 Appleton Prize to Dr. Didier Massonnet, with the citation :

"*For his outstanding work on radar imaging and satellite radar interferometry, a technique combining high frequencies, propagation and digital signal processing.*"

The Awards were presented at the Opening Ceremony of the XXVIIIth General Assembly, at the Siri Fort Auditorium in New Delhi, India, on Sunday 23 october 2005 at 4 p.m.

Booker Gold Medal

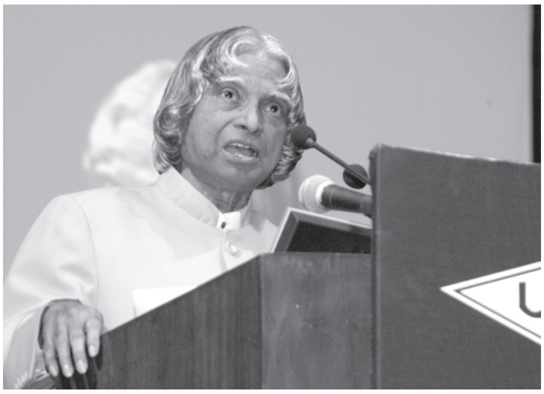
The Booker Gold Medal was awarded to Prof. Yahia Rahmat-Samii with the citation :

"For fundamental contributions to reflector antenna design and practice, near-field measurements and diagnostic techniques, handheld antennas and human interactions, genetic algorithms in electromagnetics, and the spectral theory of diffraction."

Koga Gold Medal

The Koga Gold Medal was awarded to Prof. Susan C. Hagness, with the citation :

"For contributions to the development of enhanced finite-difference time-domain methods in computational electromagnetics, and ultra-wideband microwave imaging techniques for early breast cancer detection."



Address at the inauguration of the URSI GA in New Delhi by Dr. A.P.J. Abdul Kalam, the President of India

The URSI Award winners had the opportunity to personally meet with the president of India

Group picture taken at the Opening Ceremony with Dr. A.P.J. Abdul Kalam, the President of India, Dr. A.P. Mitra, Chair of the Indian National Organising Commitee, Shri Kapil Sibal, Indian Minister of Science & Technology and Ocean Development, R.A. Mashelkar, President of INSA, the URSI Board of Officers and the URSI Awardees.

Guest Editors' Remarks

On February 6, 2005, Dr. Carl Edward Baum celebrated his 65th birthday. To commemorate this occasion, the March and June, 2005, issues of the URSI *Radio Science Bulletin* are dedicated with special sections in honor of this outstanding scientist and engineer for his unique personality and his excellent scientific achievements in the field of electrical engineering. Some of his friends, former and present colleagues, and collaborators chose the publication of these two special issues to express their affection, high esteem, kudos, gratitude, and pleasure to their partner and friend. In particular, the two guest Editors have had a close, amicable, long-term, scientific collaboration with Dr. Baum. We hope that you, the reader, will derive as much pleasure and scientific benefit from reading the papers as the contributing authors had preparing their interesting and valuable contributions. Further, we want to inform the reader that although the figures in the printed version of the March and June issues will appear with figures in black and white, color versions are also available in the downloadable files on the URSI Web site (http://www.ursi.org).

Since the first of the dedicated papers in the March issue dealt with Dr. Baum's remarkable career, we restrict ourselves here to mentioning selected characteristic properties of his personality. On viewing his long list of outstanding technical achievements and musical compositions, one naturally expects an individual who possesses highly focused, goal-oriented, scientific, managerial, and organizational qualities. The numerous honors and awards recognizing Dr. Baum attest to the fact that he excels in these qualities. With an extraordinary dedication to his profession and through the sheer force of his personality, he has promulgated and expounded his science with an almost evangelic fervor in many countries. In addition to significant contributions to general electromagnetic problems, his name stands out within the nuclear electromagnetics (NEM) community. In particular, NEMP simulators, which are located all over the world, are calculated, designed, and constructed on the advice of Carl Baum. Even former adversaries – now friends – respectfully acknowledge his contributions to EMP simulators and related topics. In recent times, Dr. Baum's efforts have concentrated on the invention and improvement of ultra-wideband technologies and their deployment in the field. He developed electromagnetic models for the transient radiation of impulse radiating antennas as well as their application. Beside his own outstanding scientific work, he initiated the development and investigation of ultra-wideband systems, particular antennas, impulse-forming devices, and signal-processing methods.

While Dr. Baum dedicates much of his time to technical endeavors, he has an avocation that deserves mention. Not only is he an accomplished pianist and trombone player, but he also is an outstanding composer of classical and religious music. For decades, he conducted a religious choir and composed numerous hymns. Symphonic groups in the US and Europe have played his compositions, and a number of CDs of his music have been recorded. His mathematical insight, which is so useful for his EM research, is also apparent in the highly complex structure and rich content of his music.

The authors, Editors, colleagues, and friends dedicate the subsequent two issues of the URSI *RSB* to Carl Edward Baum on the occasion of his sixty-fifth birthday. We wish him health, enduring creative power, and success in the coming years, and hope that our modest tribute to this extraordinary, distinguished scientist conveys our deep gratitude, affection, and admiration.

Jiirgen Nitsch
Frank Sabath

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Definition and Classification of Ultra-Wideband Signals and Devices

F. Sabath
E.L. Mokole
S.N. Samaddar

Abstract

One commonly used way to classify signals and devices is based on frequency coverage or bandwidth. Three somewhat similar, but significantly different, ultra-wideband (UWB) classification schemes from the open literature are presented. These classification schemes differ in how they define bandwidth and categorization criteria. A comparison of the categorization criteria associated with the three schemes is followed by the authors' presentation of a partially codified classification scheme that merges the existing schemes so that the merged scheme partially satisfies the criteria of each individual scheme. The second half of the article focuses on a detailed discussion of several of the numerous bandwidth definitions in the literature. The inconsistencies inherent in the three classification schemes are illustrated by applying six of the bandwidth definitions to four test signals, and comparing the results. The article concludes by suggesting further topics of discussion that could result in a common bandwidth definition and a uniform classification scheme.

1. Introduction

The last fifteen years have witnessed increased interest in ultra-wideband (UWB) systems, particularly in the areas of radar, communications, electromagnetic interference, and high-power directed energy. Since 1996, the significant development of UWB communications systems in the commercial sector has led to a definition of UWB by the US Federal Communications Commission (FCC). In attempting to characterize UWB systems in a meaningful way, researchers in each diverse area have formulated their own preferred definitions of bandwidth and UWB technologies that reflect the specific needs and viewpoints of their respective communities. Unfortunately, these definitions are not mutually consistent, which has created discourse about establishing universal UWB definitions and standards. To motivate further intercommunity discussion, this paper compares three UWB classification schemes for six definitions of bandwidth. For each bandwidth definition, the inconsistencies, advantages, and disadvantages associated with the three UWB definitions are illustrated by applying these definitions to four ideal real-valued waveforms.

According to the panel jointly formed by the US Office of the Secretary of Defense and the Defense Advanced Research Projects Agency (OSD/DARPA) [1], a UWB radar system has a bandwidth that is considerably greater than that usually associated with conventional radar and, by extrapolation, with communications and other high-power electromagnetic systems. To discuss the meaning of UWB at a sufficient depth, a more precise UWB definition, general enough to be useful for the various techniques that are employed to achieve extremely wide bandwidth, is desirable: this requires a common definition of bandwidth. Currently, at least three groups within the engineering and scientific communities (the OSD/DARPA panel, the US FCC [2], and the International Electrotechnical Commission (IEC) [3]) have articulated definitions for UWB systems and signals. Each group has attempted to define a measure of the width, B, of a spectral density, and appropriate classification criteria by using this spectral measure, to categorize signals and systems in a meaningful way. The inconsistencies among these non-coincident definitions, influenced by the differing needs and viewpoints of the respective communities, are discussed in Sections 2 and 3.

From an engineering perspective, a single unifying definition of UWB may be desirable but may not be advisable, because it may not be possible to combine the various device and signal definitions of UWB into one cohesive, consistent definition. Nonetheless, careful analyses and discussions should be conducted before definitions of UWB are established and inserted into the standards of the various technical communities. To avoid the confusion and misunderstanding that currently exist, each definition of

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UWB and the corresponding signal parameters (like bandwidth) should be minimally consistent with other UWB definitions. In addition, any deviations among definitions should be driven only by technical needs, and the reasons for the differences should be explained and well documented.

Defining UWB signals and systems unambiguously requires: (1) a definition of bandwidth, and (2) a categorization scheme in terms of bandwidth. After analyzing the differences and goals of the three existing classification schemes, a broader and hopefully more unified classification scheme, which may suit the requirements of four specific communities (radar, communication, directed energy, electromagnetic interaction), is obtained for real-valued causal signals by partially merging the definitions and criteria in Section 3. Even if this proposed merged scheme is unsuitable for all communities, it may provide a foundation for defining UWB radar.

As the definition of bandwidth is a crucial aspect of all classification schemes, six of the numerous bandwidth definitions are discussed in Section 4. Prior to detailed descriptions of the definitions, properties of real-valued signals that are of interest from a practical standpoint and basic axioms of bandwidth are discussed. In Section 5, six bandwidth definitions and three classification schemes are applied to a set of four test signals to illuminate the advantages, disadvantages, issues, and problems of these definitions and classification schemes. Although the behaviors of more realistic and less-well-behaved signals – beyond the four well-behaved test signals – will cause problems for most of the bandwidth measures presented, space limitations force discussions of other signals to be postponed to future publications. Section 6 provides a brief outlook on some challenging problems with the articulated bandwidth measures of this article.

2. Historical Background

The rapid development and postulated benefits of UWB radar led the US Office of the Secretary of Defense and DARPA to establish a UWB Radar Review Panel to assess UWB technology in the late 1980s. With a focus on UWB radar, the panel introduced the notion of the "fractional bandwidth" of a radar system as the ratio of its energy bandwidth to its center frequency (The OSD/DARPA Panel defined the energy bandwidth as the frequency range within which some specified fraction, for example, 90% or 99%, of the total signal energy lies.) Based on this parameter, the panel agreed on the following definition:

> An [*sic*] UWB radar is any radar whose [*sic*] bandwidth is greater than 0.25 regardless of the center frequency or the time-bandwidth product.

Although the panel observed that the choice of 0.25 as the defining value was largely arbitrary, their definition of UWB radar does, in some sense, represent the demarcation between conventional narrowband techniques and the need to employ special (UWB) techniques. In this sense, impulse radars are a special class of UWB radars that typically have very high peak powers and short pulse durations.

In response to the rapid development of UWB communications of the past decade, the US FCC reviewed the CFR Part 15 rules with regard to UWB transmission systems. Although the OSD/DARPA recommendations were evidently used as a basis, the FCC proposed the following somewhat different definition for UWB transmitters ([1], p. 768, §15.503):

> A UWB transmitter is an intentional radiator that, at any point in time, has a fractional bandwidth equal to or greater than 0.20 or has a bandwidth equal to or greater than 500 MHz, regardless of the fractional bandwidth.

In the FCC definition, the bandwidth is the frequency band bounded by the points that are 10 dB below the highest radiated emission, as based on the complete transmission system, including the antenna. The FCC and OSD/DARPA definitions differ on three points: (1) the selection of 0.20 instead of 0.25 as the threshold separating UWB and conventional systems, (2) the additional 500 MHz constraint, and (3) the definition of bandwidth. The difficulty with the FCC definition is that it classifies the WARLOC radar [4] – which has a 600 MHz bandwidth at a center frequency of 94 GHz – as UWB, whereas the radar community considers WARLOC to be narrowband because the fractional bandwidth is 0.0064. Moreover, the FCC definition implicitly assumes that the upper and lower 10 dB points exist and are unique, which is not always the case. For example, UWB communication systems use signals with spectra that have gaps in the signal band to protect other narrowband services. Consequently, such spectra have more than two 10 dB points. In contrast, a directed-energy system developer is interested in impulse-like waveforms that contain significant spectral amplitudes at 0 Hz. If only positive frequencies are considered, the FCC definition faces the problem that only one (the upper) 10 dB point exists. Because the 10 dB bandwidth definition diverges from the commonly used filter/signal definition of bandwidth (3 dB points), the FCC definition, which seems to be market driven, is inconsistent with well-established definitions and standards. Moreover, the FCC's three changes in UWB criteria from the OSD/DARPA definitions have greatly increased the number of unlicensed radiofrequency systems that can be called UWB, which effectively has opened spectrum usage to many more intentional radiators.

Through the International Electrotechnical Commission (IEC), the high-power directed-energy community has been formulating a standard (IEC 61000-2-13) with an alternate classification scheme for UWB [3]. The IEC scheme uses a modified version of the OSD/DARPA definition that is based on the community's experiences with impulse-radiating systems. Since many impulse waveforms have fractional bandwidths exceeding

1.9 (the theoretical maximum is 2), the IEC is currently proposing a four-band classification scheme, which uses the band ratio, b_r $(= f_h \div f_l)$ as the parameter for categorizing devices/signals. In this standard, the high (f_h) and low (f_l) frequencies are defined by the energy content: that is, 90% of the energy must lie between f_h and f_l. Although the IEC definition was derived with uneven and not-so-well-behaved spectra in mind, it has problems in uniquely defining f_h and f_l for many waveforms, including those with spectra having constant amplitude, multiple peaks, or significant sidebands. As a simple counterexample, consider the time-domain signal $\sin(at)/(\pi t)$, which is a version of the well-known ubiquitous "sinc" function in signal processing. This function has a rectangular spectrum that is unity for frequencies between $-a/(2\pi)$ and $a/(2\pi)$, and is zero otherwise. Pairs of frequencies $\{f_l, f_h\}$ that contain 90% of the signal's energy are completely specified by $\{a(\lambda-5)/(10\pi),\ \ a(\lambda+4)/(10\pi)\}$ for $0 \le \lambda \le 1$. Although the bandwidth can be uniquely determined to be a/π, the band ratio is not unique and hence is undefined under the IEC 90% energy criterion, because it can take an uncountably infinite number of values.

3. UWB Definition

As noted earlier, defining UWB devices and UWB signals unambiguously is a two-step process: (1) the notion of bandwidth must be clearly specified, and (2) the signal or device must be categorized in terms of its bandwidth. In this section, the task of categorizing the bandwidth of devices and signals is addressed under the assumption of a common universal definition of bandwidth for devices and signals. The notion of bandwidth and its impact on device/signal categorization is postponed until the next section.

A typical response to the question of what is meant by a UWB system is, "A UWB system is one that has a bandwidth considerably greater than that usually associated with conventional systems" [1]. Although this statement requires further elaboration on the meaning of bandwidth, it touches on two essential aspects that are germane to the rest of this paper: the extent of the occupied bandwidth should be the essential feature that distinguishes UWB and conventional systems/signals (that is, the designation of UWB should not be restricted to short-duration phenomena); and the term UWB should characterize systems that require the application of special and advanced techniques.

For applications like intentional electromagnetic interference, short-pulse techniques are the popular way to implement UWB systems. However, many other techniques could possibly be used to achieve extremely large bandwidths, such as frequency modulation, pseudo-random phase coding, chaotic modulation, and random noise. Consequently, the spectra of UWB systems or signals are not required to completely occupy a frequency band. Specifically, a system that sweeps over the band, or uses a time-delayed mixture of narrowband signals, should be designated UWB, as well as a system that instantaneously covers the whole band (for example, short-pulse systems). Some of the just-mentioned non-impulsive techniques cannot be implemented with existing technology. For example, a very broadband signal with a high center frequency cannot currently be generated by linear frequency modulation (the so-called chirp) with the existing technology in conventional systems, because the bandwidth is limited by the ability to maintain signal information when converting analog signals to digital data streams in radar systems.

The OSD/DARPA notion that a defining property of UWB is the need for special techniques to overcome challenging problems facing conventional systems and techniques when attempting to operate over a broad range of frequencies must be interpreted liberally, since the challenges often depend on the frequency band. For example, UWB technology (sources, switches, etc.) that supports high-power radar transmissions with high pulse repetition rates are available at 150 MHz, but are not yet feasible at 10 GHz. On the other hand, some hardware limitations and methods of signal generation/processing may have bandwidth limitations that are independent of frequency. This may explain why the US UWB communications community implemented the 500 MHz lower bound on the absolute bandwidth in the FCC's Part 15 rules.

The FCC and OSD/DARPA classification schemes use the fractional bandwidth, B_F,

$$B_F = \frac{B}{f_C} = 2\frac{f_h - f_l}{f_h + f_l} = 2\frac{b_r - 1}{b_r + 1}, \qquad (1)$$

as a frequency-independent dimensionless quantity to categorize signals and systems. One may interpret B_F as a broad indicator of the technological challenge presented by UWB radiating and receiving systems. Alternately, the IEC Technical Committee 77C has suggested using the band ratio, b_r,

$$b_r = \frac{f_h}{f_l} = \frac{2 + B_F}{2 - B_F}, \qquad (2)$$

as another normalized frequency-independent quantity. In Equations (1) and (2), f_h and f_l denote the upper and lower limits, respectively, of the band $[f_l, f_h]$, f_C is the center frequency of the band, and the bandwidth, B, is $f_h - f_l$. The exact determination of these frequencies is part of the bandwidth definition, and is discussed in the next section.

Since the relationship between B_F and b_r is straightforward, they are used interchangeably. The advantage of B_F is that its values are limited to the interval $[0, 2]$ so that its range can easily be divided into subcategories. On the other hand, that b_r lies in $[0, +\infty)$ enables a more detailed characterization of impulse-like signals and impulse-based systems. The boundary between

Band Type		Fractional Bandwidth $B_F = 2\frac{f_h - f_l}{f_h + f_l}$	Band Ratio[1] $b_r = \frac{f_h}{f_l}$
Radar / Communications	Electromagnetic Interference		
Narrowband (NB)	Hypoband (NB)	$0.00 < B_F \leq 0.01$	$0.00 < b_r \leq 1.01$
Wideband (WB)	Mesoband (MB)	$0.01 < B_F \leq 0.25$	$1.01 < b_r \leq 1.29$
Ultra-Wideband (UWB)	Sub-Hyperband (SHB)	$0.25 < B_F \leq 1.50$	$1.29 < b_r \leq 7.00$
	Hyperband (HB)	$1.50 < B_F < 2.00$	$7.00 < b_r < \infty$

Table 1: Modified Classification Scheme for Devices/Signals based on Bandwidth

conventional systems and UWB systems is more a smooth transition than a hard limit. Since this transition cannot be quantified with mathematical exactitude or by a frequency-dependent technological step for most applications, every demarcation threshold has to be chosen somewhat arbitrarily relative to existing heuristic knowledge of pertinent standardization committees or scientific communities. For example, under the following three-band classification scheme, the OSD/DARPA Review Panel [1] stated that signals having fractional bandwidths greater than 0.25 are UWB:

Narrowband, if $0.00 < B_F < 0.01$;

Wideband, if $0.01 < B_F \leq 0.25$;

Ultra-wideband, if $0.25 < B_F < 2.00$.

Since the basic principle of the above categorization criteria meets the needs of the communications community, the FCC adopted most of it. However, in the most recent version of the FCC Part 15 rules, the demarcation between wideband and UWB was decreased to 0.20.

Because practical waveforms of impulse-based systems (like impulse-radiating antennas) have fractional bandwidths exceeding 1.9, the IEC Technical Committee 77C, in their most recent draft of electromagnetic-compatibility standards, suggests a four-band classification scheme:

Narrowband, $0.00 < B_F < 0.01$,
$0.00 < b_r \leq 1.01$;

Mesoband, $0.01 < B_F \leq 1.00$
$1.01 < b_r \leq 3.00$;

Sub-Hyperband, $1.00 < B_F \leq 1.63$,
$3.00 < b_r \leq 10.00$;

Hyperband, $1.63 < B_F < 2.00$,
$10.00 < b_r < \infty$.

This classification scheme was created to describe potential high-power electromagnetic (HPEM) environments that contain a significant number of impulsive UWB signals. Under the IEC scheme, most impulse signals and impulse-based systems are classified as hyperband, while systems that use modulated sinusoidal signals (for example, chirps and finite-cycle sinusoids) tend to be classified as sub-hyperband.

Unfortunately, the IEC's choice of two threshold values (3.00 and 10.00) does not permit its bands to match the OSD/DARPA bands for $0.01 < B_F$. Consequently, the IEC's classification scheme will almost certainly cause more confusion than clarification among the various communities. As all thresholds are arbitrarily chosen, and the three-band OSD/DARPA classification scheme has been used for the last 15 years and is reasonably well accepted within the radar and communications communities, the authors believe that any unifying classification scheme should be derived from the OSD/DARPA scheme. From a more general perspective, the desire for more detailed classification can be satisfied merely by subdividing the UWB band of the OSD/DARPA scheme. The authors' suggestion for a modified classification is shown in Table 1, where unaltered OSD/DARPA bands are linked to the band types of the IEC TC 77C scheme. For practical reasons, the thresholds of two UWB subbands (sub-hyperband and hyperband) are selected because they are simple numbers for both B_F and b_r.

4. Bandwidth Definitions

In this section, six of the many definitions of bandwidth for devices and signals are addressed: 3 dB power, 10 dB power, 20 dB power, root mean square, 90% energy, and 99% energy [5]. Generally, signal bandwidths are characterized by energy content and power level, whereas devices are characterized by the amplitude and phase of the transfer function with regard to a specified performance.

In defining a device's bandwidth, one might be inclined to adopt the signal-processing approach of determining bandwidth from the magnitude (gain) of the transfer function of a device. However, a more discerning look at this idea reveals that transfer functions of devices do not necessarily satisfy conditions that are generally assumed for signals of interest, specifically, that the temporal representations of signals are real valued and their spectral amplitudes (gains) have finite energy. As a result, bandwidth definitions for signals, which are presented in Section 4.2, are not generally applicable to the transfer functions of devices, especially in the context of UWB.

In the *Dictionary of the American National Standards Institute* (ANSI) [6], the bandwidth of a receiver, an amplifier, or a network was defined as the extent of a continuous range of frequencies over which the amplitude (gain) does not differ from its maximum value by more than a specified amount. This is equivalent to signal-processing definitions, where a signal's spectrum replaces a device's transfer function. The ANSI definition is consistent and, therefore, acceptable when considering a narrowband portion of a device's spectrum. However, in a general characterization of device transfer functions, Giri and Tesche have argued that the gain of a device's transfer function is linearly increasing for low frequencies, is linearly decreasing for high frequencies, and has resonance behavior at intermediate frequencies [7]. For the impulse-radiating antennas (IRAs) of the HPEM community, radiation takes place at low frequencies, where an impulse-radiating antenna's transfer function has linearly decreasing phase and linearly increasing gain: that is, the radiated signal is the derivative of the impulse-radiating antenna's input signal. Consequently, the frequency range near the maximum gain (the resonant mode of the antenna) is not usable for HPEM applications. In contrast, the gains of antenna transfer functions associated with UWB radars have narrower bandwidths that are centered about the resonance region, because the goal of a radar system is to maximize the radiated energy in a desired direction to achieve enough signal-to-noise ratio to detect objects over a two-way propagation path. Consequently, the behavior of the gain of a device's transfer function can vary significantly according to the device's intended use. As the ANSI definition does not account for the specific behavior of a device, the bandwidth definition can identify the wrong frequency range and, as a result, give a misleading bandwidth value – which supports the argument for having distinct bandwidth definitions for signals and devices. Since the ANSI definition includes neither the phase behavior, the dispersion, nor the specific application of a device, it clearly focuses on the transmission/reception of more narrowband signals and, consequently, should not be applied to UWB devices without appropriate modifications.

4.1 Device

Another bandwidth definition for devices is found in the *IEEE Standard Definitions of Terms for Antennas* (IEEE Std 145) [8], where the bandwidth of an antenna was defined to be the range of frequencies within which the performance of the antenna, with respect to some characteristics, conforms to a specific standard. Replacing antenna by device leads to a general definition of bandwidth:

> The bandwidth of a device, component, or system is the continuous range of frequencies over which the performance, with respect to some characteristics, does not differ from some chosen behavior by more than a specified amount.

Since this definition does not provide exact mathematical limits, further interpretation and specification are needed. To this end, a device can be characterized by the amplitude and phase of its transfer function. Conventionally, the limits of bandwidth are determined by deviations of 3 dB in amplitude and 1° in phase (if a phase specification exists). Note that the preceding bandwidth definition is strongly related to the specific application or mode of operation. For example, an antenna is used in the resonant mode for standard communications and radar applications, or in the differentiating sub-resonant frequency range for HPEM applications. Generally, the bandwidths of both modes differ significantly. Although a mathematically precise definition of a device's bandwidth might be desired, it is difficult to achieve, and is seldom useful for practical applications.

4.2 Signal

The extreme diversity of signals makes it hard to construct a general definition of signal bandwidth that works for all signals. Actually, it is far easier to taper a signal and its spectrum in such a way that a particular definition makes sense. Most tapered (worst-case) signals are not physically realizable. As applications of interest (radar, communications, interference) typically transmit real-valued, causal signals with finite energy, the discussion is restricted to this class of signals.

A signal, s, with finite energy can be represented either as a function of time, t, or as a function, $\hat{S}$, of frequency, f. Both representations are related by the Fourier transform pair:

$$s(t) = \int_{-\infty}^{\infty} \hat{S}(f) e^{j2\pi ft} \, df, \qquad (3)$$

$$\hat{S}(f) = \int_{-\infty}^{\infty} s(t) e^{-j2\pi ft} \, dt. \qquad (4)$$

The time-domain function s is called the signal or waveform, and [02] is the corresponding frequency-domain representation (spectrum) [6]. Although $s(t)$ and $\hat{S}(f)$ can be complex quantities, specified through an amplitude and a phase or through real and imaginary parts, the condition that s be real-valued implies that

$$s(t) = s^{*}(t), \qquad (5)$$

where the asterisk denotes complex conjugation. Moreover, applying Equation (5) to Equation (4) yields the relation

$$\hat{S}(-f) = \hat{S}^{*}(f) \qquad (6)$$

for the spectrum at negative and positive frequencies. Hence, for the special case of real-valued signals, only half of the spectrum is required to completely specify the signal waveform. Consequently, the inverse Fourier transformation (Equation (3)) can be rewritten as [9]

$$s(t) = 2\Re\left\{\int_0^\infty \hat{S}(f) e^{j2\pi ft} df\right\}, \qquad (7)$$

where $\Re\{x\}$ denotes the real part of the argument *x*. Since the signals under consideration have finite energy, the magnitude of $\hat{S}$ must have a maximum value that is attained for at least one frequency, f_M, that is,

$$\left|\hat{S}(f)\right| \le \left|\hat{S}(f_M)\right| \qquad (8)$$

for every *f*.

4.2.1 General Axioms

Before discussing various definitions of signal bandwidth *B*, three axioms associated with the notion of spectral width are stated because every appropriate measure of the nominal width of the spectrum $\hat{S}$ must comply with this minimal set of axioms.

4.2.1.1 Bandwidth is non-negative:

$$B\left\{\hat{S}(f)\right\} \ge 0 \,. \qquad (9)$$

4.2.1.2 Bandwidth is independent of height*:*

$$B\left\{k\hat{S}(f)\right\} = B\left\{\hat{S}(f)\right\}. \qquad (10)$$

4.2.1.3 Stretching the argument of $\hat{S}$ by a constant factor c *stretches the bandwidth by* c*:*

$$B\left\{\hat{S}(cf)\right\} = cB\left\{\hat{S}(f)\right\}. \qquad (11)$$

Axiom 4.2.1.2 permits normalization of $\hat{S}$ by a constant *k*, so that $k\hat{S}(f)$ has unit area without affecting the bandwidth. Axiom 4.2.1.3 is useful in determining the bandwidth of a modulated signal.

4.2.2 Root Mean Square Bandwidth

A bandwidth definition that is often used in radar signal theory is the rms bandwidth, B_{RMS}. The Institute of Electrical and Electronics Engineers (IEEE) has a standard (IEEE Std 686-1997) [10] that used moment theory to define B_{RMS} as the second moment of the square magnitude of $\hat{S}$ about a designated frequency, typically 0 or the spectral center, where the integration is taken over all frequencies ($-\infty < f < +\infty$). Unfortunately, this definition is ambiguous, and has difficulties when used with UWB signals. In particular, since the first moment about 0 Hz (the mean frequency) is 0 Hz for every real-valued waveform, the notion of spectral center is not very meaningful, even for narrowband radar signals, since $\left|\hat{S}\right|^2$ (the power spectral density or energy density) has a maximum value at nonzero frequencies. To address this shortcoming, Rihaczek [9] defined the moments over the positive spectrum. Although the IEEE standard is not ambiguous for signals with spectral densities that have a unique absolute maximum at 0 Hz, the authors followed Rihaczek's definitions:

$$B_{RMS} = \sqrt{\frac{\int_0^\infty \left[2\pi\left(f - f_{mp}\right)\right]^2 \left|\hat{S}(f)\right|^2 df}{\int_0^\infty \left|\hat{S}(f)\right|^2 df}}, \qquad (12)$$

where the denominator of the radicand is half of the signal energy, the mean frequency, f_{mp}, over positive frequencies is given by

$$f_{mp} = \frac{\int_0^\infty f \left|\hat{S}(f)\right|^2 df}{\int_0^\infty \left|\hat{S}(f)\right|^2 df}, \qquad (13)$$

and the rms band is $\left[\max\left\{0, f_{mp} - 0.5B_{RMS}\right\}, f_{mp} + 0.5B_{RMS}\right]$, because $f_{mp} - 0.5B_{RMS}$ could be negative. The dimensions of B_{RMS} are radians per second. For well-behaved spectra, f_{mp} is usually very near to the frequency associated with the maximum value of the energy density, which is usually the carrier frequency for radiated narrowband signals.

4.2.3 *X* dB Power-Level Bandwidth

The *X* dB power-level bandwidth, B_{XdB}, is given by [5]

$$B_{XdB} = f_h - f_l, \qquad (14)$$

which is implicitly defined by the lowest (f_l) and highest (f_h) frequencies that solve

$$20\log_{10}\left|\hat{S}(f)\right| = 20\log_{10}\left|\hat{S}(f_M)\right| - X \qquad (15)$$

$$\Leftrightarrow \frac{\left|\hat{S}(f)\right|^2}{\left|\hat{S}(f_M)\right|^2} = 10^{-\frac{X}{10}},$$

for positive X. Practically speaking, B_{XdB} can be determined quickly and easily by comparing the power spectral density to a specified level. For example, B_{3dB} corresponds to values of f at which $\left|\hat{S}(f)\right|^2$ is half its maximum value. For many signals, the horizontal line associated with the specified level intersects the plot of $\left|\hat{S}(f)\right|^2$ at only two frequencies; however, this is not generally the case. For example, when $\left|\hat{S}(f)\right|^2$ has gaps, f_l and f_h are taken to be the infimum (inf) and the supremum (sup), respectively, of all solutions to Equation (15), to ensure a unique unambiguous specification of f_l and f_h. The existence of f_l and f_h is guaranteed by the finite-energy assumption.

Power-level bandwidths are used in a wide variety of applications. For example, filter design and control theory traditionally use B_{3dB}, the FCC employs B_{10dB} to define UWB signals, and the spectrum-management community uses B_{20dB} and B_{40dB}. Note that this power-level bandwidth measure is not efficient, because it includes frequencies where the energy density falls below the specified threshold. In fact, the bandwidth for a sequence of widely separated narrowband tones would be very broad, even though the set of frequencies exceeding the threshold comprises a very small percentage of the band as defined by Equations (14) and (15).

4.2.4 The *X* Fractional Energy Bandwidth

For each X in $(0,1]$, let A_X be the collection of nonnegative pairs $\{f_l, f_h\}$ of real numbers that satisfy the equation

$$\int_{f_l}^{f_h} \left|\hat{S}(f)\right|^2 df = X \int_0^{\infty} \left|\hat{S}(f)\right|^2 df \ . \qquad (16)$$

The X fractional energy bandwidth is

$$B_{XEB} = \inf\left\{(f_h - f_l) : \{f_l, f_h\} \text{ in } A_X\right\}. \qquad (17)$$

Although A_X may contain more than a single pair of frequencies, B_{XEB} is unique. For example, if the spectral magnitude is a rectangular function, the X fractional bandwidth is a single value, even though A_X contains an infinite number of distinct pairs. Generally, determining B_{XEB} in closed form for a specific signal and choice of X is not as easy to accomplish as obtaining the power-level bandwidth B_{XdB}. In fact, evaluating the integrals of Equation (16) in closed form may not be possible. Consequently, one is forced to apply numerical methods in determining each pair $\{f_l, f_h\}$, which can be very time consuming and computationally intensive.

The fractional energy bandwidth provides good information on how the signal energy is distributed in the frequency domain. This quality makes B_{XEB} a useful measure for characterizing signals in terms of their spectral occupancy (spectrum management) and electromagnetic interference with other sources (directed-energy systems and electromagnetic hardening).

5. Examples

When an equation in the literature requires an expression for bandwidth, a particular bandwidth might be indicated, the bandwidth might be unspecified, or one may wish to substitute one bandwidth measure for another. In any case, the choice of bandwidth can be problematic, because the selection or substitution could change the classification of a signal or device. To illustrate this issue, six often-used bandwidth measures are now applied to a set of four, idealized, well-behaved test signals: (1) exponentially damped sine; (2) Gaussian; (3) half-cycle sines; (4) linear frequency modulated (LFM) sine. Each of the four analytical test signals is ideal in some sense. The exponentially damped sine and the Gaussian are not physically realizable, since they have infinite temporal extent. Although the half-cycle and LFM sinusoids have finite duration, their analytical representations are not exactly realizable, because these waveforms, their first derivatives, and their second derivatives are not all zero at the endpoints of the temporal support [11]. The bandwidth measures and brief rationales for their selection are as follows:

- B_{3dB}: This is the traditionally used bandwidth definition in electrical engineering. The -3 dB power-level bandwidth has its origin in filter design, and is related to the quality factor, Q, of a damped sinusoidal waveform. ($Q = f_c \div B_{3dB}$, where f_c is the carrier frequency, with lower-case c, which is distinct from the center frequency, f_C, with upper-case C.
- B_{10dB}: The -10 dB power-level bandwidth is used by FCC Part 15 rules.
- B_{20dB}: The frequency management manual [12] defines B_{20dB} as the necessary bandwidth for radar systems.
- B_{RMS}: The rms bandwidth is often used in signal theory and signal processing as a result of its mathematically desirable properties.
- B_{90EB}: The OSD/DARPA Review Panel and the IEC TC 77C Group recommended the 90% fractional energy bandwidth.
- B_{99EB}: The 99% fractional energy bandwidth is sometimes used to characterize the spurious emissions of radar and communications transmitters.

In the next four subsections, the normalized time-domain signal and the normalized energy density are plotted for each test signal. In the plots of energy density, horizontal grid lines at the -3 dB, -10 dB, and -20 dB power levels are included as references. In addition, tables that compare the classification results for the six bandwidth measures are provided. The tables include f_l, f_h, B_F, and the relative energy, E_{rel}. The relative energy of the test signal is the ratio of the in-band energy – as determined by the particular bandwidth measure – to the total energy.

Bandwidths	f_l / GHz	f_h / GHz	B_F	Classification	E_{rel}
B_{3dB}	0.998	1.002	0.003	NB	50 %
B_{10dB}	0.995	1.005	0.010	NB	80 %
B_{20dB}	0.984	1.016	0.032	MB	94 %
B_{RMS}	0.859	1.141	0.280	UWB / SHB	99 %
B_{90EB}	0.990	1.010	0.020	MB	90 %
B_{99EB}	0.870	1.080	0.220	MB	99 %

Table 2. Classification of the exponentially damped sine with $Q = 314.47$, $\beta = 10$ MHz, and $f_c = 1$ GHz, for six bandwidth definitions.

5.1 Exponentially Damped Sine

A classical representative function for narrowband and wideband waveforms is the damped sine,

$$s(t) = s_0 e^{-\beta t} \sin(2\pi f_c t)\sigma(t), \tag{18a}$$

$$\hat{S}(f) = \frac{s_0 2\pi f_c}{(\beta + j2\pi f)^2 + 4\pi^2 f_c^2}, \tag{18b}$$

where $\sigma(t)$ is the unit step function and f_c is the carrier frequency. The behavior of the power spectral density depends on the ratio, β/f_c, of the damping factor to the carrier frequency. Specifically, for β/f_c less than the threshold $\left[4\pi^2/(8\pi^2-1)\right]^{1/2} \cong 0.712$, the maximum, f_M, is approximately equal to f_c, and the spectrum for positive frequencies is essentially symmetric about f_M. As β/f_c increases to this threshold, the spectrum becomes increasingly asymmetric over the positive frequencies, and f_M migrates towards dc (0 Hz), which it reaches when $\beta/f_c = 0.712$. To illustrate these behaviors, the waveform and power spectral density are plotted for two representative values of β/f_c: one much less than the threshold (0.01), and one less than but near to 0.712 (0.60).

In the case of a low damping factor relative to f_c ($\beta = 10$ MHz and $f_c = 1$ GHz, that is, a medium quality factor of $Q = 314.47$), the time-domain representation, *s*, consists of a large number of cycles (Figure 1a), and the spectrum is essentially symmetric about $f_c \cong f_M$ (Figure 1b). Consequently, all bandwidth definitions are well defined for this signal (Table 2). Many engineers classify the damped sinusoidal waveform that is depicted in Figure 1 as wideband. With the exception of classifications that use B_{3dB} or B_{10dB}, which identify the signal as narrowband, the bandwidth definitions agree with this popular view.

Increasing β/f_c (decreasing Q) reduces the number of effective cycles in the time domain and increases the low-frequency content of the spectrum. By taking this to the extreme, the spectrum of the damped sine can be made UWB with a significant power level at dc. For example, when $\beta = 0.6$ GHz and $f_c = 1$ GHz, $|\hat{S}|^2 > -20$ dB for $0 \text{ Hz} \le f \le 1.7 f_c$ and $f_M \cong f_c$ (Figure 2). For this type of waveform, the spectrum is no longer symmetric about the peak frequency, f_M. For some bandwidth definitions (B_{20dB}, B_{RMS}, B_{99EB}), the lower frequency, f_l, goes to zero, and the fractional bandwidth is two (Table 3). Since the calculation of b_r would require dividing by zero in that situation, b_r would not be defined for this waveform,

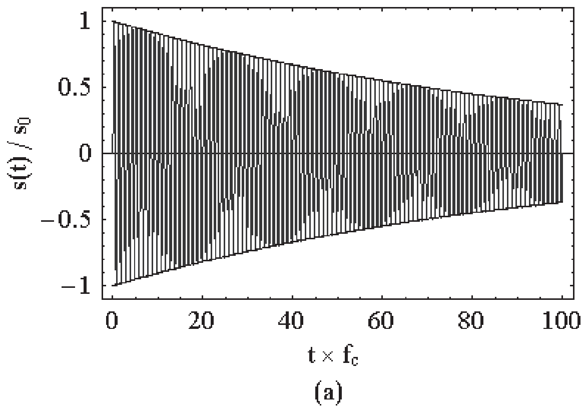

Figure 1a. A time-domain representation of an exponentially damped sine for $\beta = 10$ MHz and $f_c = 1$ GHz.

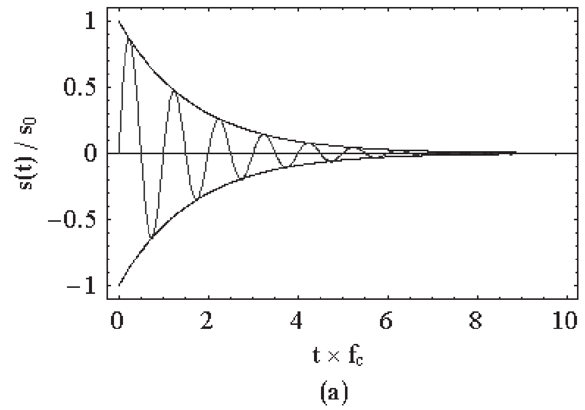

Figure 1b. A frequency-domain representation of an exponentially damped sine for $\beta = 10$ MHz and $f_c = 1$ GHz.

Bandwidths	f_l / GHz	f_h / GHz	B_F	Classification	E_{rel}
B_{3dB}	0.89	1.09	0.19	MB	50 %
B_{10dB}	0.65	1.25	0.64	UWB / SHB	82 %
B_{20dB}	0.00	1.70	2.00	UWB / HB	98 %
B_{RMS}	0.00	2.05	2.00	UWB / HB	99 %
B_{90EB}	0.45	1.40	1.03	UWB / SHB	90 %
B_{99EB}	0.00	1.85	2.00	UWB / HB	99 %

Table 3. Classification of the exponentially damped sine with $Q = 5.15$, $\beta = 0.6$ GHz, and $f_c = 1$ GHz, for six bandwidth definitions.

which is why the IEC TC 77 C recommended imposing the condition that $f_l \geq 1$ Hz. To avoid this difficulty, the modified classification of Table 1 requires b_r to equal f_h for $0 \text{ Hz} \leq f_l \leq 1$ Hz. Consequently, b_r takes the value of f_h for waveforms with significant power levels at dc, like high-damping-factor or impulse signals.

Generally, for all values of the damping factor, the B_{3dB} and B_{10dB} bands respectively contain 50% and approximately 80% of the signal energy. Due to the dominant and relatively sharp peak in the spectrum, the B_{20dB} band contains at least 90% of the signal energy. Therefore, B_{20dB} can be used as a rule-of-thumb approximation for B_{90EB}.

5.2 Gaussian Pulse

The Gaussian pulse is a widely used mathematical model for impulse and impulse-like signals. In this article, the Gaussian pulse is used to stress the behavior of bandwidth definitions with regard to impulse, transient, and short-pulse signals. The Gaussian transform pair is given by

$$s(t) = s_0 e^{-\frac{1}{2}\left(\frac{t}{t_p}\right)^2}, \tag{19a}$$

$$\hat{S}(f) = s_0 t_p \sqrt{2\pi} e^{-2\pi^2 \left(t_p f\right)^2}. \tag{19b}$$

Plots of the time-domain signal and its Fourier transform are displayed in Figure 3. For positive frequencies, the spectrum is a strictly monotonically decreasing function with a peak at $f = 0$ Hz (Figure 3b). Thus, all six bandwidth definitions, regardless of whether they are based on power level or energy content, yield $f_l = 0$ Hz (Table 4), which implies that the center frequency, f_C, is $f_h/2$. Similarly to the previous example, $b_r = f_h$ by the footnote to Table 1. Essentially, B_F is two for all impulse signals with $f_h > 1$ kHz.

To elaborate further, consider two Gaussian signals with $t_p = 100$ ps and 1 s. Both pulses are classified as UWB because $B_F = 2$. However, the 100 ps short-pulse signal is

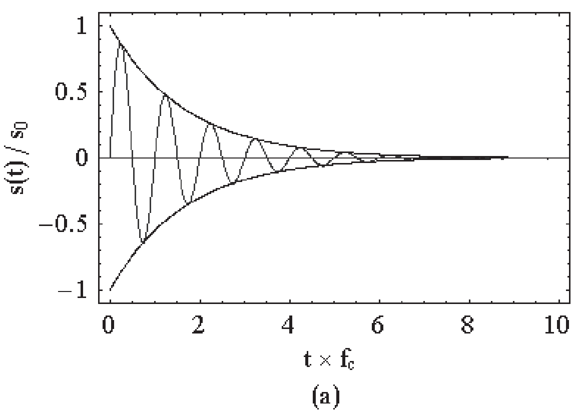

Figure 2a. A time-domain representation of a damped sine for $\beta = 0.6$ *GHz and* $f_c = 1$ *GHz.*

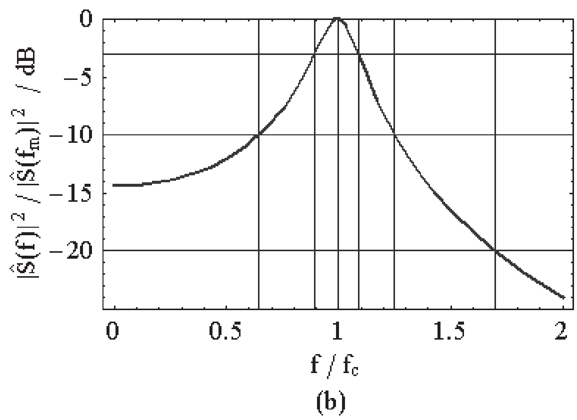

Figure 2b. A frequency-domain representation of a damped sine for $\beta = 0.6$ *GHz and* $f_c = 1$ *GHz.*

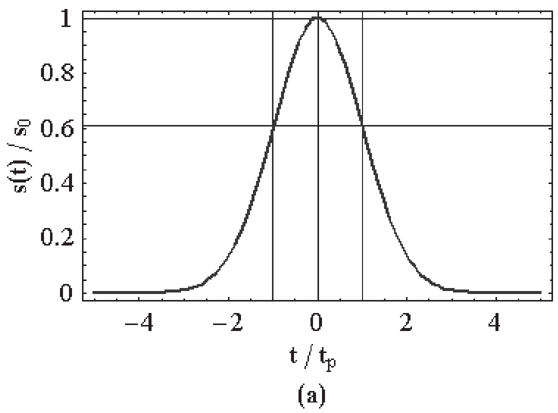

Figure 3a. A time-domain representation of a Gaussian pulse for arbitrary t_p.

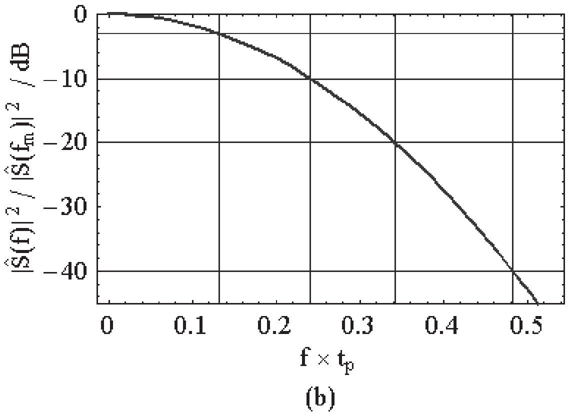

Figure 3b. A frequency-domain representation of a Gaussian pulse for arbitrary t_p.

far more technologically challenging. With this in mind, the IEC defined b_r to distinguish between technologically challenging UWB signals and other UWB signals. The modified classification scheme of Table 1 retains this feature of sub-categorizing UWB signals.

Even though the Gaussian pulse is a non-causal signal, the monotonicity and significant asymmetry of the Gaussian spectrum over the positive frequencies (Figure 3b) cause problems for the B_{RMS} definition. Equations (12) and (13) yield a mean frequency, f_{mp}, of $1/\left(2t_p\pi\sqrt{\pi}\right)$, which differs substantially from the peak frequency, f_M, of 0 Hz, and an rms band of $\left\{0, f_{mp}+\left[(\pi-2)/(2\pi)\right]^{1/2}/\left(2t_p\right)\right\}$.

5.3 Finite Half-Cycle Sine

A waveform that has been discussed in connection with UWB radar is *n* half cycles of the sine function [11]. The mathematical representation of this waveform and the corresponding Fourier transform are

$$s(t)=s_0\sin\left(2\pi f_c t\right)\left[\sigma(t)-\sigma\left(t-\frac{n}{2f_c}\right)\right], \quad (20a)$$

$$\hat{S}(f)=-\frac{s_0}{2\pi}\frac{f_c}{f^2-f_c^2}\left[1-(-1)^n e^{-jn\pi\frac{f}{f_c}}\right]. \quad (20b)$$

In contrast to the previous two waveforms, the spectrum of this waveform is characterized by the nulls of its power spectral density,

$$\left|\hat{S}(f)\right|^2=\frac{s_0^2}{2\pi^2}\frac{f_c^2}{\left(f^2-f_c^2\right)^2}\left[1-(-1)^n\cos\left(n\pi\frac{f}{f_c}\right)\right],$$

which occur at

Bandwidths	$f_l\, t_p$	$f_h\, t_p$	B_F	Classification	E_{rel}
B_{3dB}	0.00	0.132	2.00	UWB / HB	76.0 %
B_{10dB}	0.00	0.242	2.00	UWB / HB	96.8 %
B_{20dB}	0.00	0.342	2.00	UWB / HB	99.8 %
B_{RMS}	0.00	0.303	2.00	UWB / HB	99.3 %
B_{90EB}	0.00	0.185	2.00	UWB / HB	90 %
B_{99EB}	0.00	0.290	2.00	UWB / HB	99 %

Table 4. Classification of a Gaussian pulse for six bandwidth definitions.

$$f_{km} = \begin{cases} \frac{2k}{2m} f_c, & k \in \{0,1,2,\ldots\} - \{m\},\ n = 2m, \\ & \text{and } m \in \{1,2,3,\ldots\}, \\ \frac{2k+1}{2m+1} f_c, & k \in \{0,1,2,\ldots\} - \{m\},\ n = 2m+1, \\ & \text{and } m \in \{0,1,2,\ldots\}. \end{cases}$$

As the locations of the nulls indicate, the behavior of $\left|\hat{S}\right|^2$ depends on whether one is considering full cycles ($n = 2m$) or half cycles ($n = 2m+1$) of the sine function in Equation (20a). In either case, the power spectral density has a value of $\left[n s_0 / (4 f_c) \right]^2$ at f_c, which is close but not equal to a local maximum. For very broadband signals ($n \le 10$), the local maximum differs significantly from f_c, although it lies between f_c and one of its two nearest null frequencies. As *n* increases, the local maximum approaches f_c. In particular, this local maximum is the global maximum, f_M, for even *n*, and f_M is $0.837470 f_c$ for $n = 2$ (one cycle), $0.998480 f_c$ for $n = 20$ (10 cycles), and $0.999985 f_c$ for $n = 200$ (100 cycles). When *n* is odd ($= 2m+1$), $\left|\hat{S}\right|^2$ has a dc component of $\left[s_0 / (\pi f_c) \right]^2$, which is significant for small *m*. Specifically, the ratio of $\left|\hat{S}\right|^2$ at 0 Hz to $\left|\hat{S}\right|^2$ at f_c is 1.62 (2.1 dB) for $m = 0$, is 0.18 (-7.4 dB) for $m = 1$, and is 0.06 (-11.9 dB) for $m = 2$. As *m* increases, the dc component becomes negligible, and the global maximum approaches f_c.

The portion of the plot of a power spectral density between two nulls that don't include f_M is called a sidelobe. The height of each sidelobe is a function of *n* and the order of the sidelobe (that is, first, second, third, etc., sidelobes). In some cases, one or more sidelobes exceed the chosen power threshold, resulting in multiple pairs of crossing points at the threshold. If only the crossing points nearest the global maximum are used to determine f_l and f_h, the resulting bandwidth will not accurately represent the frequency band occupied by this signal. For wideband signals ($n \le 10$), a significant part of the spectrum would be lost by filtering above the first null, which would severely degrade the information content of the signal. In contrast to a spectrum consisting of a superposition of narrowband signals, the notches in the spectrum of a wideband signal do not separate the spectra of sub-signals. Actually, some applications of UWB communication (for example, broadband over power lines) intentionally design these notches to protect other narrowband signals and services. Consequently, the lowest and the highest crossing points, $\inf\{f_l\}$ and $\sup\{f_h\}$, may be appropriate for determining the power-level bandwidth to avoid inaccurately characterizing the bandwidths of wideband signals and signals with spectral notches.

To make the preceding discussion more concrete, the one-cycle sine (a UWB signal) and its normalized power spectral density are plotted in Figure 4. The peak power level of the first sidelobe between $2 f_c$ and $3 f_c$ is 18.12 dB below the absolute maximum value at $0.837470 f_c$ in the main lobe between 0 Hz and $2 f_c$. On inspecting Figure 4b, one clearly sees that the -20 dB line intersects the curve in four places. Consequently, B_{20dB} includes a significant portion of the first sidelobe. A similar situation occurs for B_{99EB}, since the main lobe contains only 98.93 % of the signal energy (Table 5). On comparing the classifications in Table 5, one observes that the bandwidth measures form three groups: Group 1 (B_{3dB} and B_{90EB}) contains only the main lobe and classifies the signal as UWB/SHB; Group 2 (B_{20dB}, B_{RMS}, and B_{99EB}) includes the first sidelobe and classifies the signal as UWB/HB; and Group 3 (B_{10dB}) acts like an interface between Groups 1 and 2, since it classifies the signal as UWB/HB but contains only the main lobe.

The preceding example illustrates that characterizations of wideband and UWB signals in the frequency domain require more parameters than narrowband signals. For narrowband signals, one can assume that a single peak, containing almost the entire signal energy, dominates the spectrum. In contrast, the signal energy of wideband/UWB signals is spread over an extremely wide range of frequencies, wherein the amplitude can vary significantly (notches and multiple peaks). Consequently, using only the calculated bandwidths of wideband and

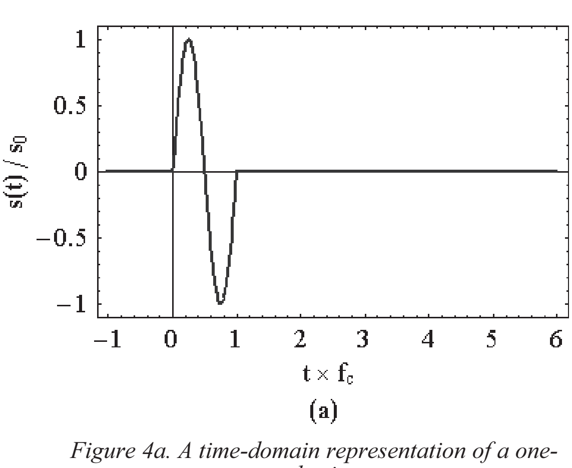

Figure 4a. A time-domain representation of a one-cycle sine.

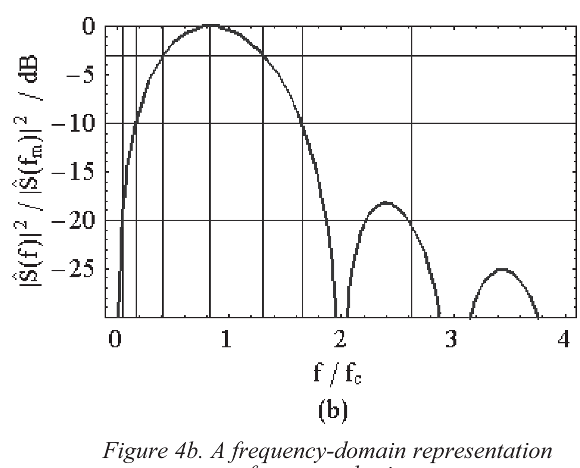

Figure 4b. A frequency-domain representation of a one-cycle sine.

Bandwidths	f_l / f_c	f_h / f_c	B_F	Classification	E_{rel}
B_{3dB}	0.410	1.30	1.04	UWB / SHB	79.05 %
B_{10dB}	0.170	1.65	1.63	UWB / HB	97.18 %
B_{20dB}	0.050	2.62	1.93	UWB / HB	99.58 %
B_{RMS}	0.000	2.24	2.00	UWB / HB	99.04 %
B_{90EB}	0.305	1.445	1.30	UWB / SHB	90 %
B_{99EB}	0.051	2.215	1.91	UWB / HB	99 %

Table 5. Classification of the one-cycle sine for six bandwidth definitions.

UWB signals provides incomplete and fragmentary characterizations of the signals. Therefore, additional parameters, like the waviness (ripple), which characterizes the variation of the amplitude in the specified band, are needed for a more complete understanding of signal characterizations.

5.4 Linear Frequency-Modulated Sine (Chirp)

A classical radar signal is the linear frequency-modulated (LFM) waveform, which is implemented by modulating the sine function to increase the signal bandwidth. This waveform and pulse compression in a radar receiver are used to simultaneously obtain the energy of a long-duration signal and the resolution of a high-energy short-duration signal. Pulse compression "is implemented in high-power radar applications that are limited by voltage breakdown if a short-pulse were to be used" [13]. The linear frequency-modulated waveform, also called chirp modulation, sweeps linearly over a frequency band during a given time interval, and is given by [14]

$$s(t) = s_0 \sin\left[2\pi f_c\left(t + \frac{1}{2}\mu t^2\right)\right]\left[\sigma(t) - \sigma(t - T_n)\right], \tag{21a}$$

with the pulse duration

$$T_n = \frac{1}{\mu}\left(-1 + \sqrt{1 + \frac{n\mu}{f_c}}\right),$$

where n is the number of half cycles, s_0 is the nominal amplitude, and m is the chirp rate. For $0 \le t \le T_n$, the instantaneous frequency, $f(t)$, is $f_c + \mu t$, which varies from f_c (the carrier and starting frequency) to $f_c + \mu T_n$. Evaluating the Fourier transform yields

$$\hat{S}(f) = \frac{1}{2j\sqrt{2 f_c \mu}}$$

$$\left\{ e^{-j\pi\frac{(f-f_c)^2}{f_c\mu}} \left[-C(x_1) - jS(x_1) + C(x_2) + jS(x_2)\right] \right.$$

$$\left. -e^{j\pi\frac{(f+f_c)^2}{f_c\mu}} \left[C(x_3) - jS(x_3) - C(x_4) + jS(x_4)\right] \right\}, \tag{21b}$$

with

$$x_1 = \sqrt{2}\,\frac{f - \sqrt{f_c^2 + n f_c \mu}}{\sqrt{f_c \mu}},$$

$$x_2 = \sqrt{2}\,\frac{f - f_c}{\sqrt{f_c \mu}},$$

$$x_3 = \sqrt{2}\,\frac{f + \sqrt{f_c^2 + n f_c \mu}}{\sqrt{f_c \mu}},$$

$$x_4 = \sqrt{2}\,\frac{f + f_c}{\sqrt{f_c \mu}},$$

where $C(x)$ and $S(x)$ are the Fresnel integrals

$$C(x) = \int_0^x \cos\left(\frac{\pi}{2} y^2\right) dy,$$

$$S(x) = \int_0^x \sin\left(\frac{\pi}{2} y^2\right) dy.$$

The relatively constant run of the in-band magnitude spectrum is the main advantage of the linear frequency-modulated waveform for practical applications. The

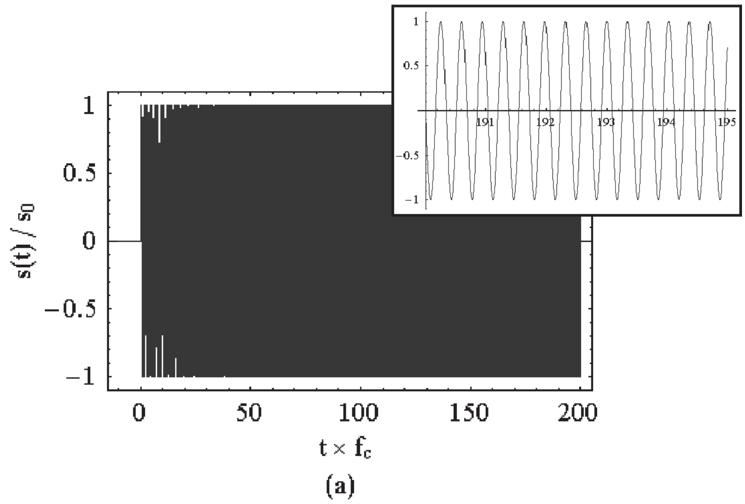

Figure 5a. A time-domain representation of a linearly frequency-modulated waveform for $n = 800$ and $\mu = 0.01 f_c$.

steepness of the edges and the waviness of the in-band spectrum are functions of the number, n, of half cycles. Both n (the duration of the signal) and μ (the modulation factor) determine the width of the occupied frequency band. Since bandwidth provides a measure of the spectral occupancy, one expects the value of an appropriately defined bandwidth to be closely related to the width of the rectangular part of the spectrum. For the example depicted in Figure 5, this means that the calculated bandwidth is close to $2 f_c$, $f_l \cong f_c$, and $f_h \cong 3 f_c$. With the exception of B_{RMS}, the bandwidth definitions under consideration roughly satisfy this expectation, since f_l and f_h of Table 6 differ from the expected values by less than $\pm 0.17 f_c$ (by less than $\pm 0.04 f_c$ for B_{3dB} and B_{10dB}). As a result of the sharp gradients at the spectral edges, B_{RMS} significantly overestimates the occupied band, by a factor of two.

The linear frequency-modulated waveform is of interest in the context of this article because the approximately rectangular form of the spectrum creates a special classification problem if B_{90EB} is used. That is, one cannot uniquely determine a frequency band, although B_{90EB} is well defined. In the example ($n = 800$ and $\mu = 0.01 f_c$), at least two pairs of high and low frequencies, $\{1.06, 2.84\}$ and $\{1.16, 2.94\}$, satisfy the requirement that 90% of the signal energy lies between them for the minimal width of $1.78 f_c$ ($= B_{90EB}$). The pair $\{f_l, f_h\}$ cannot be uniquely defined, since at least two intervals exist that contain 90% of the signal energy and have the identical minimal width.

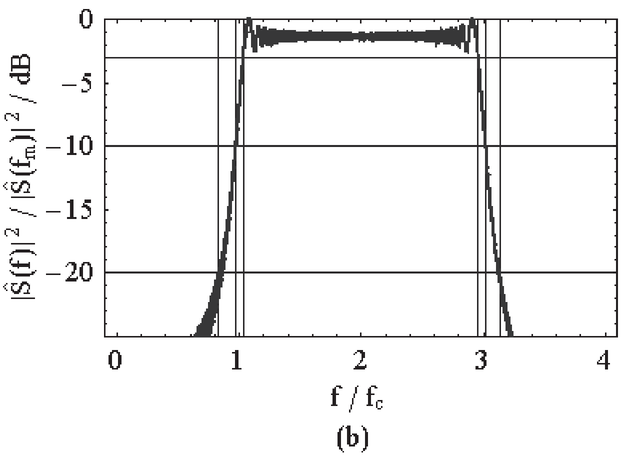

Figure 5b. A frequency-domain representation of a linearly frequency-modulated waveform for $n = 800$ and $\mu = 0.01 f_c$.

Bandwidth	f_l / f_c	f_h / f_c	B_F	Classification	E_{rel}
B_{3dB}	1.04	2.96	0.96	UWB / SHB	97.21 %
B_{10dB}	0.97	3.02	1.03	UWB / SHB	99.16 %
B_{20dB}	0.83	3.14	1.16	UWB / SHB	99.83 %
B_{RMS}	0.18	3.82	1.82	UWB / HB	99.91 %
B_{90EB}	1.06	2.84	0.92	UWB / SHB	90 %
	1.16	2.94	0.87	UWB / SHB	90 %
B_{99EB}	0.98	3.02	1.01	UWB / SHB	99%

Table 6. Classification of the LFM waveform with $n = 800$ and $\mu = 0.01 f_c$ for six bandwidth definitions.

6. Challenging Questions

Although the four test signals evaluated in this paper are considered well behaved, they pose challenging problems for the articulated bandwidth definitions and classification schemes. For example, two very different signals can be classified as hyperband (UWB): (1) an impulse-like 10 ps Gaussian signal with a bandwidth, *B*, in the tens of GHz and a lower frequency of 0 Hz (set $t_p = 10$ ps in Table 4); and (2) an extremely long duration pulse with a nearly flat magnitude spectrum and *B* on the order of a few Hz (a linear frequency-modulated signal with a very large number, *n*, of half cycles and a very low chirp rate, μ). That these two extremes would belong to the same category perhaps suggests the need for a general classification scheme with more than one parameter to distinguish signal types, if a scheme is to be applicable for arbitrary signals and applications. Typically, UWB has been associated with short-pulse signals only: a large number of articles and standardization publications discuss UWB only with regard to short-pulse signals. In contrast, the proposed UWB definition and classification scheme does not require the frequency range to be completely occupied and, consequently, non-impulsive signals may be UWB.

Many bandwidth definitions suffer from not being well defined for an arbitrary waveform. It is unclear whether a specific bandwidth definition exists for each waveform. In the case of a rectangular spectrum with a beginning frequency f_b and an ending frequency f_e, the energy bandwidth B_{90EB} is equal to $0.9(f_e - f_b)$, because any interval with a width of $0.9(f_e - f_b)$ contains 90% of the signal energy. However, the power-level bandwidth B_{XdB} is not defined for $X > 0$, since no horizontal line intersects the power spectral density, except for $X = 0$. Although B_{90EB} is uniquely determined, the fractional bandwidth and the band ratio are not defined, because many f_l in $[f_b, f_b + 0.9 f_e]$ satisfy $(f_h - f_l) = 0.9(f_e - f_b)$.

Another problematic issue arises when signal spectra with notches or multiple peaks cause trouble for the power-level bandwidth definitions, since the chosen power level may intersect the magnitude spectrum at more than two points. Even if the fractional energy bandwidth is uniquely defined for this kind of signal spectrum, its interpretation is not without problems. Specifically, a nonuniform distribution of the notches and peaks can induce a nonuniform energy distribution over the frequency band, and consequently signals with identical energy-bandwidth values could significantly differ. For example, the notches of one signal could match the peaks of a second signal, and visa versa. One means for addressing this issue would be to introduce a parameter (peak-to-valley ratio) that describes the ripple content or waviness of the magnitude spectrum within a specified band.

Finally, a parameter that has been ignored by UWB definitions and classification schemes is the phase spectrum. This omission may be acceptable for the classification of signals, but phase plays an important role in describing and characterizing devices. In this vein, one might want to quantify the goodness of a UWB device by specifying how closely the magnitude and phase of the device's transfer function approximate constant and linear functions, respectively. This goodness criterion is equivalent to quantifying how closely a device's output matches its input. One possible means of quantifying this goodness is to calculate the fidelity [15] between the input and output signals.

Deeper discussions of these challenging questions, as well as treating less ideal signals like spectra with wide energy spreads and medium strong peaks, are the subject of future research.

7. Summary

This article has discussed the definition and classification of UWB signals and devices in terms of frequency coverage and bandwidth. Three apparently similar UWB classification schemes have been compared, and the differences in how they define bandwidth and categorization criteria have been highlighted. After analyzing the differences and goals of these classification schemes, more unified categorization criteria, which may suit the requirements of some technical communities (radar, communication, electromagnetic interaction, directed energy), have been proposed for real-valued causal signals by partially merging the definitions and criteria of the three schemes. The new categorization criteria are formed by taking the OSD/DARPA criteria as the kernel and by realigning the OSD/DARPA ranges for Wideband and UWB to match the IEC scheme, with a couple of modifications to IEC thresholds. The Mesoband regime is reduced to agree with the OSD/DARPA Wideband designation ($0.01 < B_F \le 0.25$); the UWB regime is split into Sub-Hyperband ($0.25 < B_F \le 1.50$) and Hyperband ($1.50 < B_F < 2.00$).

The second component of creating a viable classification scheme is appropriately defining bandwidth. Many of the inconsistencies inherent in the three classification schemes and the associated challenges have been illustrated by applying six of the many bandwidth definitions in the literature to four ideal test signals, and by comparing the results. Since the signals under consideration are real-valued, these bandwidths are defined for nonnegative frequencies only, and fall into three classes: power-level based (B_{3dB} , B_{10dB} , B_{20dB}); energy based (B_{90EB} , B_{99EB}); and moment based (B_{RMS}). When the parameters of the four signals are chosen so that they are considered UWB in some sense, only the impulse-like signal (Gaussian) is uniquely classified (Hyperband UWB) for all six bandwidths under the new categorization criteria. In contrast, the exponentially damped five-cycle sine has the widest variety of classifications: Wideband by B_{3dB} ; Sub-Hyperband UWB by B_{10dB} and B_{90EB} ; and Hyperband UWB by B_{20dB} , B_{RMS} , and B_{99EB} . On averaging over the six bandwidths, the signals in order of decreasing spectral width are: Gaussian (most broadband); single-cycle sine; exponentially damped five-cycle sine; and linear frequency-modulated (least broadband). Although some pros and cons of these six bandwidth definitions have been discussed, no conclusion on whether one bandwidth definition is preferable over the others has been reached. This begs the question of whether using additional parameters would permit a unique classification of real causal signals across all bandwidth definitions.

Even if additional parameters are not useful in providing a unique signal classification over the various bandwidth measures, they certainly could be useful for evaluating devices. For example, phase plays an important role in describing and characterizing devices. Consequently, quantifying how closely the phase and magnitude of a device's transfer function approximate constant and linear functions, respectively, will indicate how accurately the device replicates its input signal.

Although the authors feel that the proposed categorization criteria offer a good compromise to existing criteria (OSD/DARPA, IEC, FCC), the new classification scheme is incomplete because a bandwidth definition has not been selected. This is the more difficult aspect of specifying a useful, unambiguous, and possibly broad classification scheme. It may well be that a new classification scheme must include several definitions of bandwidth, or may have to be sufficiently vague to permit broad interpretation. In any case, additional investigations of other bandwidth definitions are needed before resolving whether a new classification scheme is possible. Given the open questions associated with spectrally based classification schemes for signals and devices, one should exercise great care in attempting to define terms like UWB radar.

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Quantitative Comparison Between Matrix Pencil Method and State-Space-Based Methods for Radar Object Identification

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Abstract

Approximating a function by a sum of complex exponentials to identify the nature of electromagnetic scatterers is treated with three model-based parameter-estimation methods. In particular, the Matrix Pencil Method and two State-Space-Based Harmonic-Retrieval methods are compared quantitatively. It is known that these methods generate very similar results in the absence of noise in the data and have only minor differences between them when the data is contaminated by noise. Since a quantitative comparison of the three methods has not been reported in the literature, this paper compares them by determining how accurately and quickly they predict the poles of the transient impulse responses of five electromagnetic systems: thin wire; perfectly conducting sphere; finite closed cylinder; dielectric sphere; composite metallic-dielectric sphere. It is important to note that these techniques are applied directly to the data and not to the covariance matrix, as noise statistics require additional information that is not available and the noise in electromagnetic scenes is generated typically by undesired signals in the form of a base-line shift in the measurement hardware instead of thermal background noise.

1. Introduction

In this paper, methods that directly estimate radar signals from scattered data, as opposed to methods that use a covariance matrix, are compared. The key discriminators in the comparisons are the speed and accuracy of the methods. In particular, three model-based parameter-estimation techniques, the Matrix Pencil [1-6] and two State-Space Harmonic-Retrieval Methods [7,8], are selected for analysis. The fundamental parameters to be estimated are the natural resonances of the scattering structure of interest. The natural resonances are the poles of the impulse response of an object, which correspond to the generalized eigenvalues of a pertinent Hankel matrix for the Matrix Pencil Method (MPM) and to the zeroes of an appropriate determinant for the State-Space Methods.

The accuracies of the methods vary with the amount of noise in the data. To ascertain the speed and accuracy of the methods, scattering data from three types of objects (three perfect conductors, a dielectric, a composite metallic dielectric) are simulated with a known electromagnetics code. Each method approximates the real time-domain scattered field with a finite sum of complex exponentials. An essential question is how many sinusoids are needed to characterize the scatterer accurately.

These Matrix Pencil and State-Space Methods, sometimes called direct-data-domain (DDD) methods, derive the resonances from the transfer function of a discrete-time representation of the impulse response. Approximating a function by a sum of complex exponentials has been frequently used for identification. Usually, the kth sample $y(k)$ of the time-domain electromagnetic scattered field is represented by a finite sum of damped sinusoids

$$y(k) = x(k) + n(k)$$

$$= \sum_{m=1}^{M} |c_m| e^{[(\alpha_m + j\omega_m)kT_s + j\phi_m]} + n(k) \qquad (1)$$

$$= \sum_{m=1}^{M} R_m z_m^k + n(k)$$

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for $k = 0,1,\ldots,N-1$, where N is the number of time samples, $x(k)$ is the noise-free data, is the noise sequence, $|c_m|$ and are the amplitudes and phases of the sinusoids, α_m and ω_m are the damping factors and angular frequencies, M is the number of complex exponentials to be determined, and T_s is the sampling period. To express $y(k)$ in terms of poles z_m in the z-domain (right side of (1)), define

$$R_m = |c_m|\, e^{j\phi_m} \tag{2}$$

$$z_m = e^{(\alpha_m + j\omega_m)T_s} \tag{3}$$

where R_m are complex residues. Since (1) approximates the complete discrete time-domain response (which includes both early-time and late-time responses) by superposing damped sinusoids, the complex resonant poles of (3) can be different from the poles determined with a numerical solution of the corresponding electric-field integral equation (EFIE), which seeks complex values of the frequency that make the determinant of the impedance matrix zero.

In this paper, we are interested in the minimum order of the approximation in terms of accuracy and running time. It is well known that the Matrix Pencil and State-Space Methods generate very similar results for the exact-data case, have minor differences for the noisy-data case [7], and are equivalent to a first-order approximation [1] in the values of the variance of the poles from additive noise in the data. Both methods use the properties of a Hankel matrix and the singular value decomposition (SVD), which play an important role in many signal-processing applications. The most pertinent feature of the Hankel matrix is that its rank for the ideal case reflects the order of the corresponding system – hence the number of nonzero singular values corresponds to the rank of the matrix. Consequently, the set of singular values will be used to determine the rank, as well as to estimate the deviation of the matrix from a lower rank one [8].

Although many variations of the Matrix-Pencil and State-Space Methods appear in the literature, only three approaches are chosen for this study: the Total Least Squares Matrix Pencil Method (TLS-MPM) [9]; the normal state-space approach (SS1) using SVD [8]; and the state-space approach (SS2) using the Extended Impulse Response Grammian [10-12]. In the selected state-space approaches, Markov parameters (which are related to the impulse response of the system) are used to obtain the poles of the system. In contrast to traditional signal processing, each method is applied directly to the data and not to a covariance matrix – that is, this methodology is deterministic rather than statistical. The allure of a deterministic model is that the parameters of interest have smaller Cramer-Rao bounds than a stochastic model [13] in the presence of background noise.

These three methods and the procedures for obtaining the associated time-domain impulse-response sequences are summarized. Then the accuracies and execution times of the methods are compared by considering five examples: a thin conducting wire structure; a perfectly conducting sphere; a finite closed cylinder; a dielectric sphere; and a composite metallic-dielectric sphere.

2. Total Least Squares Matrix Pencil Method (TLS-MPM)

The TLS-MPM approach is an efficient and robust method to fit noisy data with a sum of complex exponentials [9]. To implement the TLS-MPM, one forms the matrix $[Y]$,

$$[Y] = \begin{bmatrix} y(0) & y(1) & \cdots & y(L) \\ y(1) & y(2) & \cdots & y(L+1) \\ \vdots & \vdots & & \vdots \\ y(N-L-1) & y(N-L) & \cdots & y(N-1) \end{bmatrix}_{(N-L)\times(L+1)} \tag{4}$$

from the N samples $\{y(0),\ldots,y(N-1)\}$ of the input y, where the pencil parameter L is less than N. For efficient noise filtering, L is chosen between $N/3$ and $N/2$. Then the SVD of $[Y]$ is given by [14]

$$[Y] = [U][\Sigma][V]^H \tag{5}$$

In (5), $[U]$ is an $(N-L)\times(N-L)$ unitary matrix whose columns are the eigenvectors $[Y][Y]^H$, $[V]$ is an $(L+1)\times(L+1)$ unitary matrix whose columns are the eigenvectors $[Y]^H[Y]$, $[\Sigma]$ is a diagonal matrix containing the r positive singular values of $[Y]$, and r is the rank of $[Y]$. The superscript H denotes conjugate transpose and

$$s(1) \ge s(2) \ge \ldots \ge s(r) > 0 \cdot$$

At this stage, the number of exponentials is determined by the ratio of the smallest singular value $s(r)$ to the largest one $s(1)$. For a singular value σ_c , consider the relation

$$\frac{\sigma_c}{s(1)} \approx 10^{-p}, \tag{6}$$

where p is the number of significant decimal digits in the data. Equation (6) is used to cull the singular values. For example, if the data is accurate to 3 significant digits, then the singular values for which the ratio in (6) is less than 10^{-3} are essentially noise singular values, and they will not be used.

Next, construct the 'filtered' matrix $[V']$,

$$[V'] = [v_1, \ldots, v_M], \tag{7}$$

so that it contains only the M dominant right singular vectors of $[V]$; that is, the $L+1-M$ right singular vectors from $M+1$ to $L+1$ corresponding to the small singular values, are discarded. Therefore,

$$[Y_1] = [U][\Sigma'][V_1']^H, \tag{8}$$

$$[Y_2] = [U][\Sigma'][V_2']^H, \tag{9}$$

where $[V_1']$ is obtained from $[V_1']$ by deleting the last row of $[V_1']$, $[V_2']$ is obtained by removing the first row of $[V_1']$, and $[\Sigma']$ is obtained from the M columns of $[\Sigma]$ corresponding to the M dominant singular values. The poles of the signals are given by the nonzero eigenvalues of

$$\left\{[V_1']^H\right\}^+ [V_2']^H, \tag{10}$$

which are the same as the eigenvalues of

$$[V_2']^H \left\{[V_1']^H\right\}^+. \tag{11}$$

The + superscript denotes the pseudo-inverse of a matrix [14].

Once the M poles $z_m = \exp(\alpha_m + j\omega_m)T_S$ are known for $1 \le m \le M$, the residues R_m are solved from the following least-squares problem

$$\begin{bmatrix} y(0) \\ y(1) \\ \vdots \\ y(N-1) \end{bmatrix} = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ z_1 & z_2 & \cdots & z_M \\ \vdots & \vdots & & \vdots \\ z_1^{N-1} & z_2^{N-1} & \cdots & z_M^{N-1} \end{bmatrix} \begin{bmatrix} R_1 \\ R_2 \\ \vdots \\ R_M \end{bmatrix}. \tag{12}$$

The sampling time T_S is typically assumed to be unity in a digital system. However, for real data, one needs to specify a value for T_S. The damping coefficients α_m and frequencies ω_m in the continuous s domain are related to the discrete poles z_m in the z domain by $s_m = \alpha_m + j\omega_m$ and $z = \exp(sT_S)$.

3. State-Space Approach 1 (SS1)

Consider a stable, linear, time-invariant, discrete-time system of degree n described by the minimal realization

$$\begin{aligned} [x(k+1)] &= [A][x(k)] + [B]u(k), \\ y(k) &= [C][x(k)], \end{aligned} \tag{13}$$

where $[x(k)]$ is the length-n state vector at discrete time k and $[A]$ is the $n \times n$ state transition matrix. Generally, the input u and output y can be vectors, the well known multiple-input multiple-output (MIMO) problem. However, for the sake of brevity, $u(k)$ and $y(k)$ are scalars in this discussion. The poles of the system are then the eigenvalues of the state-space matrix $[A]$. In addition, $[B]$ and $[C]$ are auxiliary matrices of dimension $n \times 1$ and $1 \times n$, respectively. Therefore, for a single-input single-output system, the scalar Markov parameters $\{h(k)\}$, which essentially are the samples of the impulse response of the system, are given by

$$h(k) = [C][A]^{k-1}[B]. \tag{14}$$

Define the sequence of Hankel matrices $\{[Mq(k,l)]\}_q$, (equation 15 - see below)

where the index q is a nonnegative integer and $K \times L$ is the dimension of M_q. The elements of each M_q represent the impulse response of the system [7,8].

For a minimal realization of the matrices $[A]$, $[B]$, and $[C]$ of degree n and N time samples ($N \ge 1$), the rth-order reduced model is obtained by using the following procedure. First, generate the square Hankel matrix $[M_1(N+1, N+1)]$ and perform an SVD of this matrix to

$$[M_q(k,l)] = \begin{bmatrix} h(q) & h(q+1) & \cdots & h(q+l) & \cdots & h(q+L) \\ h(q+1) & h(q+2) & \cdots & h(q+1+l) & \cdots & h(q+1+L) \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ h(q+k) & h(q+k+1) & \cdots & h(q+k+l) & \cdots & h(q+k+L) \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ h(q+K) & h(q+K+1) & \cdots & h(q+K+l) & \cdots & h(q+K+L) \end{bmatrix} \tag{15}$$

obtain

$$[M_1] = [U][\Sigma][V]^H , \tag{16}$$

where

$$[\Sigma] = Diag\left[s(1),\ldots,s(r),e(r+1),\ldots,e(N+1)\right],$$

with

$$s(1) \geq s(2) \geq \ldots \geq s(r) \geq e(r+1) \geq \ldots \geq e(N+1) \geq 0.$$

The orthogonal matrices $[U]$ and $[V]$ are the right and the left singular vectors of $[M_1]$, respectively. It is assumed that $[M_1]$ has *r* dominant singular values and the remaining $1 + N - r$ singular values are close to zero and are considered noise. So, if $\left[M_1(N+1, N+1)\right]$ has an effective rank *r*, then all the singular values $e(i)$ should be zero. When the singular values $e(i)$ are small nonzero values, the rank of $[M_1]$ is not too far from *r*. The second step consists of rearranging (16) such that

$$[M_1] = \left[\bar{U}\right]\left[\bar{V}\right], \tag{17}$$

where

$$\left[\bar{U}\right] = [U][\Sigma]^{1/2} \text{ and } \left[\bar{V}\right] = [\Sigma]^{1/2}[V].$$

Finally, $\left[\bar{U}\right]$ and $\left[\bar{V}\right]$ are used to obtain the filtered state-space matrices $[A_r]$, $[B_r]$, and $[C_r]$. Specifically, the reduced state-space matrices are

$$[A_r] = \left[\bar{U}_1\right]^+ \left[\bar{U}_2\right] = \left[\bar{V}_1\right]^+ \left[\bar{V}_2\right], \tag{18}$$

$$[B_r] = \left[\bar{V}\right]^{(1)}, \tag{19}$$

$$[C_r] = \left[\bar{U}\right]^{(1)}, \tag{20}$$

where $\left[\bar{U}_1\right]$ is the first *N* block rows and the first *r* columns of $\left[\bar{U}\right]$, $\left[\bar{U}_2\right]$ is the last *N* block rows and the first *r* columns of $\left[\bar{U}\right]$, $\left[\bar{V}_1\right]$ is the first *r* rows and the first *N* block columns of $\left[\bar{V}\right]$, $\left[\bar{V}_2\right]$ is the first *r* rows and the last *N* block columns of $\left[\bar{V}\right]$, $\left[\bar{U}\right]^{(i)}$ is the *i*th block row and the first *r* columns of $\left[\bar{U}\right]$, $\left[\bar{V}\right]^{(i)}$ is the first *r* rows and the *i*th block column of $\left[\bar{V}\right]$.

By using these state-space matrices, one can generate the impulse response *h* and the system transfer function *H* of the reduced system,

$$h(k) = [C][A][B]^{k-1}, \tag{21}$$

$$H(z) = [C_r][z I_r - A_r]^{-1}[B_r], \tag{22}$$

where I_r is the $r \times r$ identity matrix. The *n* poles z_m of the reduced system $(1 \leq m \leq n)$ are the eigenvalues of the state matrix $[A_r]$ and correspond to the damping coefficients and the frequencies in the *s* domain through the relationship

$$z_m = e^{(\alpha_m + j\omega_m)T_s} \tag{23}$$

This concludes the overview of how the poles are computed in the state-space approaches. Once the poles are obtained the residues can be obtained using (12).

4. State-Space Approach 2 (SS2) with Extended Impulse Response Grammian (EIRG)

Similar to section 3, consider a stable, linear, time-invariant, discrete-time, single-input and single-output system of degree *n* described by the minimal realization

$$\begin{aligned}\left[x(k+1)\right] &= [A]\left[x(k)\right] + [B]u(k),\\ y(k) &= [C]\left[x(k)\right].\end{aligned} \tag{24}$$

The Extended Impulse Response Grammian $[P_N]$ of order *N* for a system of degree *n* is defined as

$$[P_N] = \sum_{k=0}^{\infty} \begin{bmatrix} h_{k+1}^H h_{k+1} & h_{k+1}^H h_{k+2} & \cdots & h_{k+1}^H h_{k+N} \\ h_{k+2}^H h_{k+1} & h_{k+2}^H h_{k+2} & \cdots & h_{k+2}^H h_{k+N} \\ \vdots & \vdots & & \vdots \\ h_{k+N}^H h_{k+1} & h_{k+N}^H h_{k+2} & \cdots & h_{k+N}^H h_{k+N} \end{bmatrix} \tag{25}$$

for each positive integer *N* and for every $n \leq N$, where

$$h_k = [C][A]^{k-1}[B] \tag{26}$$

and $\{h_k\}$ is a set of Markov parameters or an impulse-response sequence. The infinite sum of matrices in (25) exists when the impulse response is stable. In this case, the summation is equivalent to the matrix of element-wise summations. Analogous to the decomposition of $[M_1]$ in (16), the SVD of the Extended Impulse Response Grammian (EIRG) is

$$[P_N] = [U][\Sigma][V]^H , \quad (27)$$

where

$$[\Sigma] = Diag\left[s(1),\, s(2), \ldots s(r), e(r+1), \ldots, e(N)\right],$$

with

$$s(1) \geq s(2) \geq \ldots \geq s(r) \geq e(r\ +\ 1) \geq \ldots \geq e(N) \geq 0.$$

As noted earlier, the singular values $\{e(r+1),\ldots,e(N)\}$ should be zero if the matrix $[P_N]$ has rank *r*, and the rank of $[P_N]$ is approximately *r* when the remaining singular values are very small. Define

$$\begin{aligned} [X] &\equiv \left([U][\Sigma]^{1/4}\right)^H = [\Sigma]^{1/4}[U]^H , \\ [X]_1 &\equiv \left[[X]^{\langle 1\rangle}, \cdots, [X]^{\langle r\rangle}\right], \\ [X]_2 &\equiv \left[[X]^{\langle 2\rangle}, \cdots, [X]^{\langle r+1\rangle}\right], \end{aligned} \quad (28)$$

where $[X]^{\langle j\rangle}$ is the *j*th column block of the matrix $[X]$ truncated to the first *r* elements. Although the form of (27) is the same as (5) and (16), the decomposition in (28) differs from (18).

In this case, the reduced state matrices $[A_r]$, $[B_r]$, and $[C_r]$ are given by

$$[A_r] = [X_2][X_1]^+ \text{ if and only if } [A_r][X_1] = [X]_2 , \quad (29)$$

$$[B_r] = [X]^{\langle 1\rangle} , \quad (30)$$

$$\left[\tilde{C}\right] = [U][\Sigma]^{-1/4} , \quad (31)$$

$$[C_r] = \left[\tilde{C}\right]^{(1)} , \quad (32)$$

where $\left[\tilde{C}\right]^{(1)}$ is the *i*th block row of matrix $[\tilde{C}]$ truncated to the first *r* elements. If the reduced state-space matrices $[A_r]$, $[B_r]$, and $[C_r]$ are known, then the poles of the system can be extracted using the outlined procedure for SS1.

5. Computation of Poles for Temporal Scattered Field

In this study, the temporal back-scattered electromagnetic fields from five objects are used as impulse-response sequences for the three direct-data-domain methods (MPM, SS1, SS2). To obtain the simulated scattered fields in the time domain, the frequency-domain back-scattered fields are first calculated with WIPL-D [15], a method-of-moments code. WIPL-D uses an electric field integral equation (EFIE) for conducting structures and the PMCHW (Poggio-Miller-Chang-Harrington-Wu) Equation for composite structures. The time-domain data is calculated by computing the inverse Fourier transform of the frequency-domain result. Before taking the inverse Fourier transform of the frequency domain data, a Gaussian window is applied to limit the bandwidth of the simulations.

The advantages of the Gaussian window are two fold: (1) it provides a smooth roll off in time and frequency; and (2) it is well suited for numerical computation, as it generates essentially band-limited frequency-domain data. The expression for this window in the time domain is [16]

$$g(t) = \frac{1}{\sigma\sqrt{\pi}} e^{-\tilde{a}^2} , \quad (33)$$

with

$$\gamma = \frac{(ct - ct_0)}{\sigma} . \quad (34)$$

The parameter *c* is the speed of light in free space, t_0 is a time delay that represents the peak time shift from the origin, and σ is the pulse width that can be defined so that the peak value has dropped to about 2% at time *t* for $ct - ct_0 = \pm 2\sigma$. Figure 1(a) shows an example of the temporal Gaussian pulse, where $\sigma = 1.0$ and lm. The unit lm denotes a light meter, which is the length of time for an electromagnetic wave to travel 1m. When the medium is free space, 1lm = 3.33564ns. Since the Fourier transform of a Gaussian function is Gaussian, the Fourier transform of (33) is

$$G(f) = \frac{1}{c} e^{-(\frac{\pi\sigma f}{c})^2} e^{-j2\pi f t_0} , \quad (35)$$

and the frequency band corresponding to the pulse width is plotted in Figure 1(b).

To illustrate the three fundamental data types (smooth, rapidly fluctuating, noise-like), five geometrically simple objects are analyzed: a thin conducting wire, a perfectly conducting sphere, a perfectly conducting finite closed cylinder, a dielectric sphere, and a composite metallic-dielectric sphere.

5.1 Thin Conducting Wire

The first example is a thin-wire scattering element of

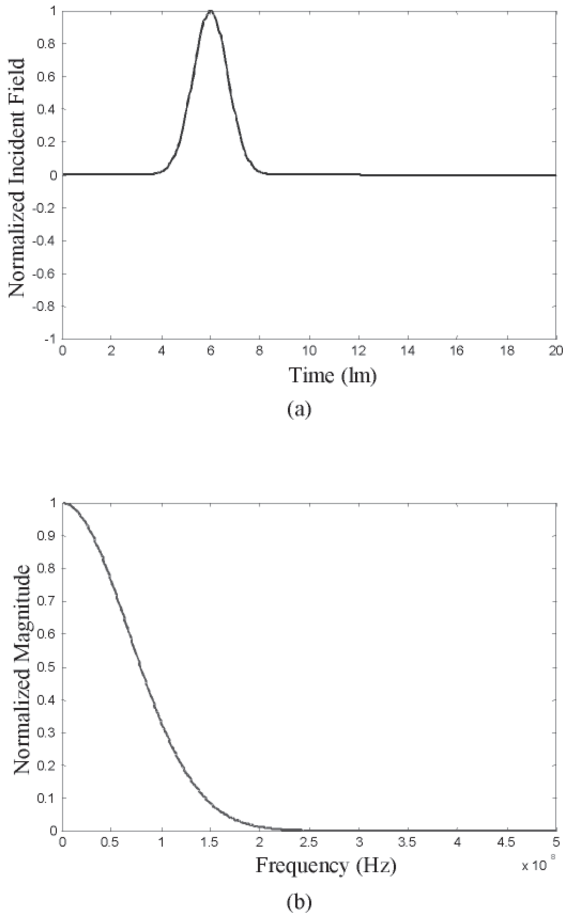

Figure 1. Plots of a Gaussian incident field in the (a) time domain and (b) frequency domain that are used for excitation of the electromagnetic scatterer.

length L (= 50 mm) and diameter d (= 0.5 mm), so that the aspect ratio L/d is 100. The wire is excited by a pulse of electromagnetic radiation that is incident along a direction that is 45° from the vertical orientation of the wire, and the incident field is polarized in the θ direction. Here θ is the

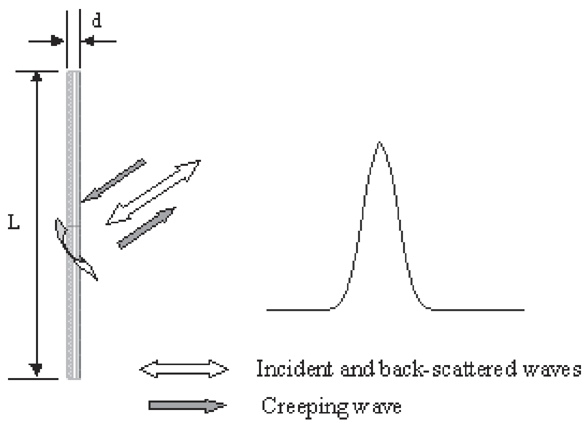

Figure 2. A wire scatterer model with a wave incident from $\theta = 45^{\circ}$, where θ is defined from the vertical axis.

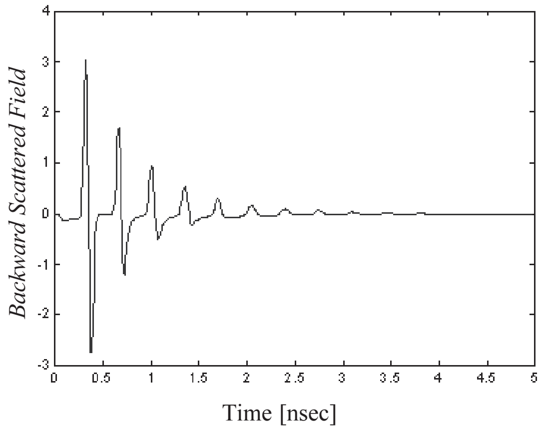

Figure 3. Back-scattered field in the time domain for a thin-wire scatterer.

angle from the vertical axis of the wire. The normalized back-scattered field in the frequency domain is computed at 1028 sample frequencies between 200 MHz and 100 GHz with the WIPL-D code [15]. A Gaussian window with $\sigma = 0.0035$ and $ct_0 = 14\sigma$ is applied to the frequency-domain data to limit the maximum frequency. Figure 3 displays the time-domain response of the back-scattered field, which is derived by taking the inverse fast Fourier transform (IFFT) of the Gaussian-windowed frequency-domain data. When taking the IFFT, some zero padding of the frequency-domain data is used to increase the time-domain resolution. The sampling frequency of the resulting time-domain data is 4 times that of the highest frequency of interest.

Since the temporal target signal is real valued, its Fourier transform has a complex conjugate pole pair, which corresponds to two singular values and constitutes one damped sinusoid. Since simulations require a finite number of damped sinusoids, the selected number of damped sinusoids determines the number of singular values. After calculating the corresponding poles, the time-domain signal is reconstructed either by using those poles and the appropriate residues in the Matrix Pencil Method or by using the zeros in the State-Space Methods. The root-mean-

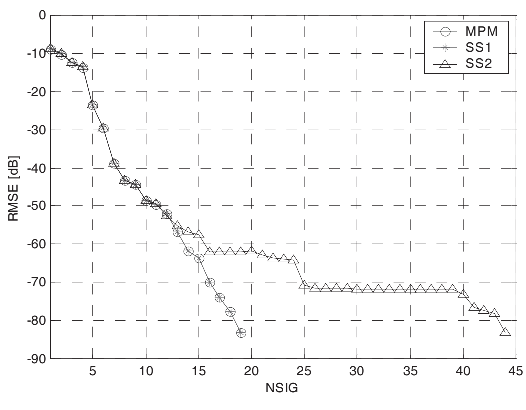

Figure 4. RMS errors versus number of damped sinusoids of the reconstructed signal from a wire scatterer for the Matrix Pencil Method (MPM) and two State-Space Methods (SS1,SS2).

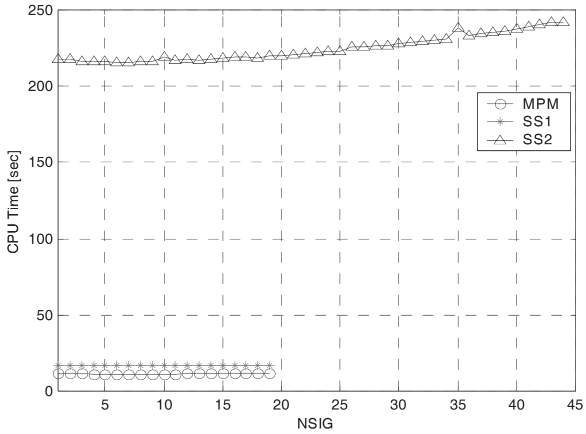

Figure 5. CPU time taken by each method for the analysis of the thin-wire scatterer.

square (RMS) error between the original signal and reconstructed signal is also computed.

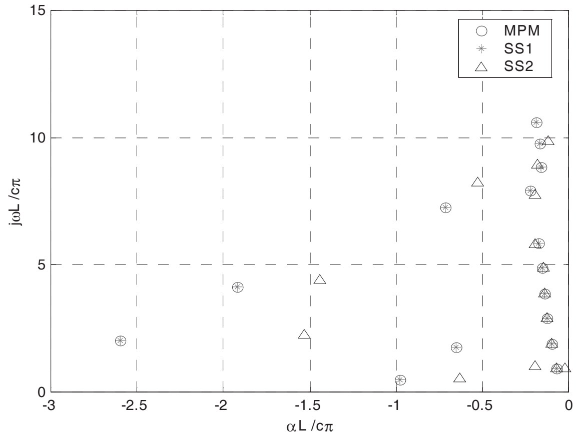

Figure 7. Extracted poles for NSIG = 15 for a thin-wire scatterer. The *x*-axis and *y*-axis represent the real and the imaginary values of the pole, normalized with respect to the length *L* of the antenna, and *c* is the speed of light in free space.

Figure 4 shows that the RMS error (RMSE) decreases with the number (NSIG) of damped sinusoids. Since one damped sinusoid consists of a complex conjugate pole pair, it uses two singular values. Circles represent the results using the Matrix Pencil Method (MPM), the asterisks indicate the results for the first State-Space Method (SS1), and the triangles are the results for the second State-Space Method (SS2). For an error threshold of -80 dB, the RMSEs of MPM and SS1 are the same when the error falls below the threshold, and the transient response is approximated with 19 damped sinusoids. The RMSE is the same for each method up through 12 sinusoids; however, for SS2 it decreases slowly and requires 44 damped sinusoids to approximate the transient response before it goes below the threshold. Figure 5 displays the CPU time taken by each method. All simulations have been carried out on the same PC: a 2.4-GHz Intel Pentium IV with 2 GB of RAM. Average CPU times for MPM, SS1, and SS2 respectively are 11.4 s, 16.8 s, and 224.8 s. Since the CPU time for the MPM is 68% of that for the SS1 and 5% of that for the SS2, the MPM is the fastest of the three methods.

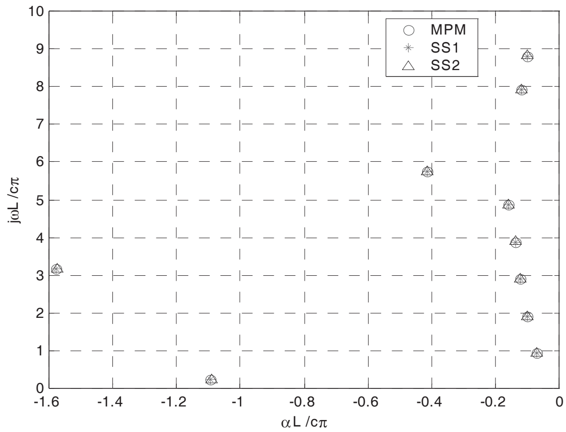

Figure 6. Extracted complex poles for NSIG = 10 of a thin-wire scatterer. The *x*-axis and *y*-axis represent the real and the imaginary values of the pole, normalized with respect to the length *L* of the antenna, and *c* is the speed of light in free space.

Figures 6 and 7 show the pole plots for NSIG = 10 and 15, respectively. Only the node locations in the second quadrant are shown, because complex poles are symmetric about the real axis. For NSIG = 10, all poles are the same for

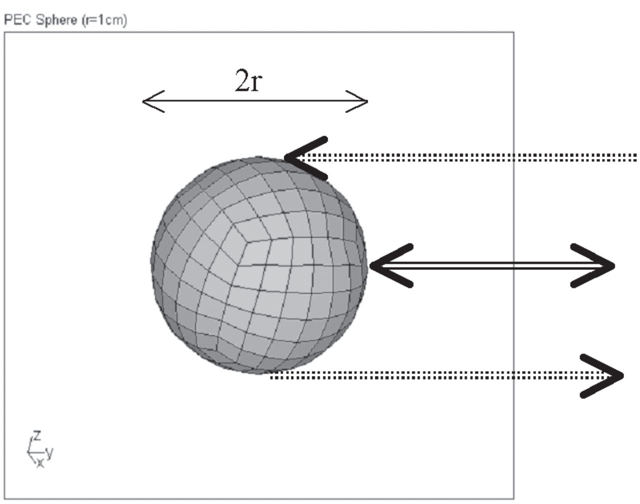

Figure 8. Model of a perfectly conducting sphere.

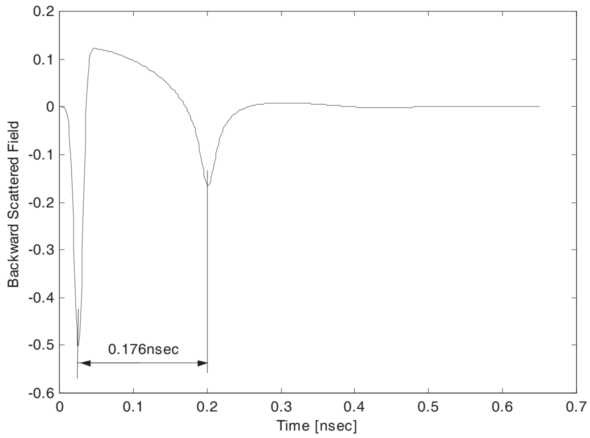

Figure 9. Back-scattered field in the time domain for perfectly conducting sphere.

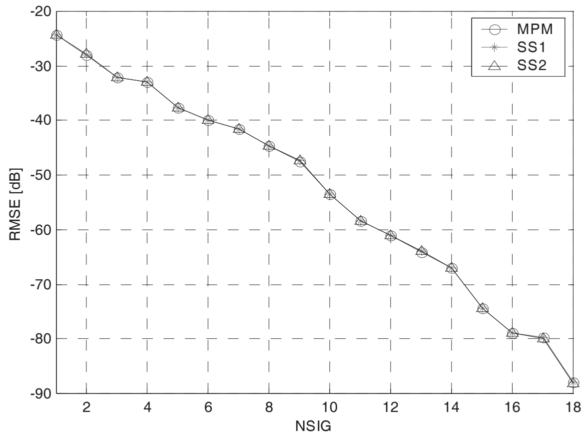

Figure 10. RMS error of the reconstructed signal for a perfectly conducting sphere.

the three methods, but for NSIG = 15, the locations of the poles for the SS2 method differ from the other two methods. Consequently, the MPM and SS1 provide reliable answers for this scattering object.

5.2 Perfectly Conducting Sphere

As a second example, consider a conducting sphere of radius 1 cm (Figure 8), with a *z*-polarized incident field coming from the side. The back-scattered field has been obtained using WIPL-D over 10-1500 GHz. The inverse-transformed time-domain data (Figure 9) exhibits two kinds of pulses, a directly reflected pulse and a creeping wave. The time difference associated with these contributions to the back-scattered field is about 0.176 ns, which is in good agreement with the calculated value of 0.1714 ns $\left[=10^{-8}(2+\pi)3r\right]$. Pole extractions and approximations with the two methods are done with the entire time-domain impulse response. Figure 10 shows that the RMSEs are the same for the three methods and that the -80 dB threshold for the singular values is satisfied for 18 damped sinusoids. However, the elapsed CPU times are much different (Figure 11). Specifically, the average CPU times for the MPM, the SS1, and the SS2 respectively are 1.4 s, 2.3 s, and 34.2 s. The time for the MPM is 60% of that for the SS1 and 4% of that for the SS2. Although the magnitude of the back-scattered field for the sphere is roughly 8 times smaller than that for the wire, the relative values of the CPU times are similar, but with slightly smaller percentages for the sphere.

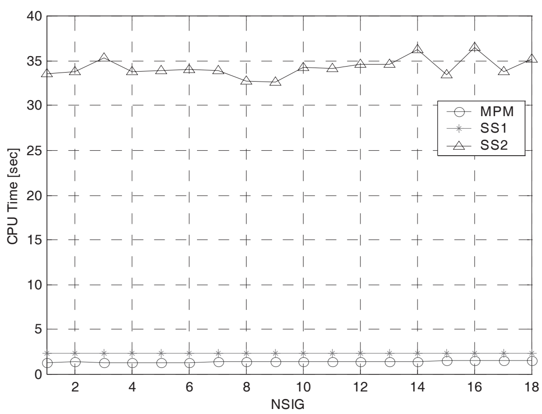

Figure 11. CPU times of MPM, SS1, and SS2 for the perfectly conducting sphere.

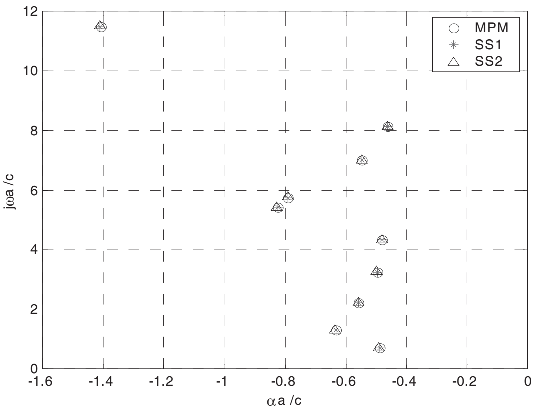

Figure 12. Extracted poles for NSIG = 10 for a perfectly conducting sphere. The *x*-axis and *y*-axis represent the real and the imaginary values of the pole, normalized with respect to the radius *a* of the sphere, and *c* is the speed of light in free space.

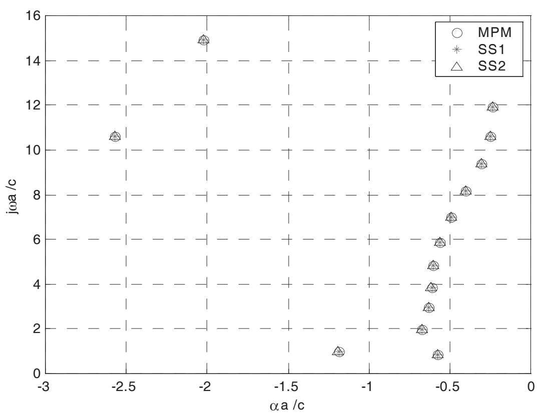

Figure 13. Extracted poles for NSIG = 14 for a perfectly conducting sphere. The *x*-axis and *y*-axis represent the real and the imaginary values of the pole, normalized with respect to the radius *a* of the sphere, and *c* is the speed of light in free space.

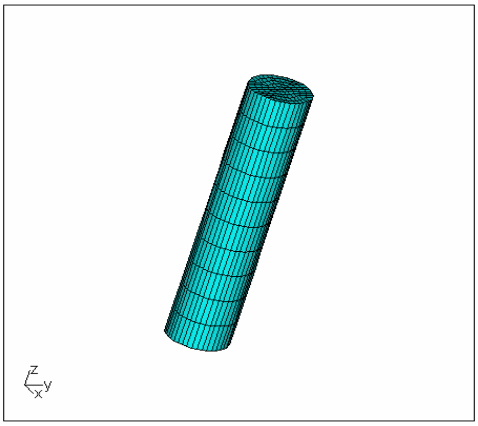

Figure 14. Closed finite conducting cylinder model with an aspect ratio of $L/d = 5$.

Figures 12 and 13 plot the extracted complex resonant poles for NSIG = 10 and 14. The extracted poles are identical for each method, which means that the singular values are equal, even though the starting Hankel matrix for each method is different. Again, the three DDD methods perform equally well.

5.3 Finite Closed Conducting Cylinder

For the third example, consider a finite closed cylinder (Figure 14). The length and diameter of the cylinder are 1 m and 0.2 m, respectively, so that the aspect ratio (length/diameter) is 5. The angle of the θ-polarized incident field is 45° from the axis of the cylinder (*z* axis). In this example, the parameters for the Gaussian window that is applied to limit the bandwidth of the frequency domain result (10-1500 GHz) are $\sigma = 0.15$ and $ct_0 = 8.5$. After windowing, the back-scattered field is reconstructed from the inverse Fourier transform (Figure 15). The return is negligible after 55 ns.

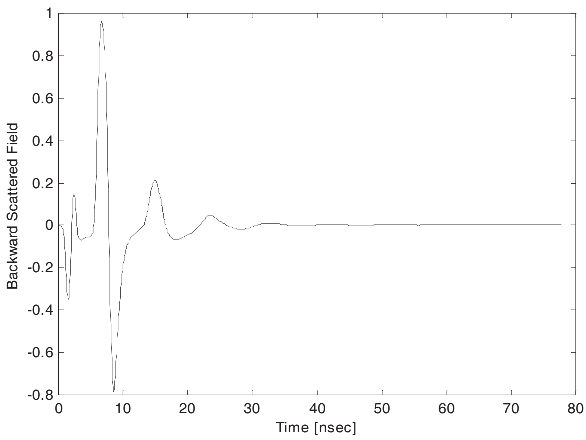

Figure 15. Back-scattered field in the time domain for a finite closed conducting cylinder.

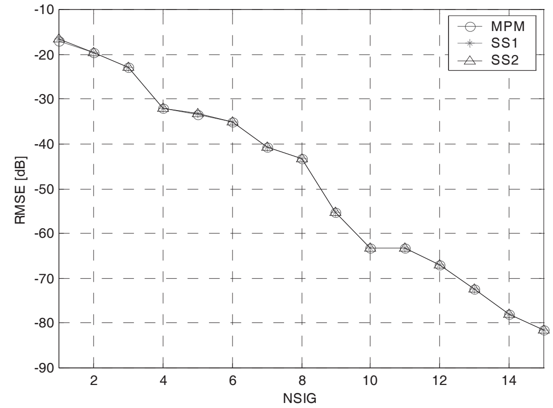

Figure 16. RMSEs in the reconstructed signal for finite closed conducting cylinder.

Pole extractions and approximations with the three methods are done with this time-domain signal of Figure 15. For each method, the RMSEs are the same and the threshold is satisfied with 15 damped sinusoids (Figure 16).

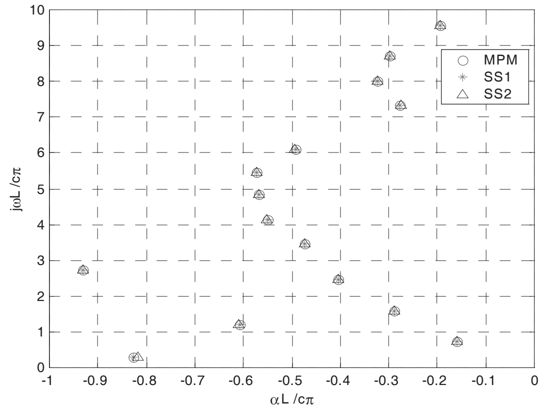

Figure 17. Extracted poles for NSIG = 15 for a finite closed cylinder. The *x*-axis and *y*-axis represent the real and the imaginary values of the pole, normalized with respect to the length *L* of the cylinder, and *c* is the speed of light in free space.

Also, the locations of the extracted poles are nearly identical (Figure 17). However, the elapsed CPU times are very different from those of the preceding examples. In particular, the average CPU times for the MPM, the SS1, and the SS2 are 19.1 s, 24.7 s, and 391.5 s. The time for the MPM is about 71% of that for SS1 and 4.87% of that for the SS1. Similar to the preceding example, the MPM is at least 25% faster than the State-Space Methods.

5.4 Dielectric Sphere

The fourth example is a dielectric sphere with $\varepsilon_r = 4$ and a 0.5-m radius, and the incident field is coming from the top of the sphere along the *z*-axis and is *x*-polarized. The back-scattered field has been obtained using WIPL-D in the frequency range of 10-1500 MHz. The parameters of the

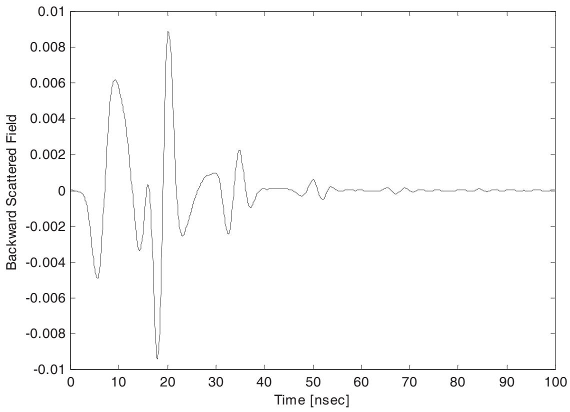

Figure 18. Back-scattered time-domain field for a dielectric sphere ($\varepsilon_r = 4$ and a 0.5-m radius).

Gaussian window are $\sigma = 0.56$ and $ct_0 = 5\sigma$. The inverse-transformed time-domain data, which provides an approximate band-limited impulse response for the structure, is shown in Figure 18.

The extracted poles are almost the same for all three methods, with small differences apparent for SS2 (NSIG = 10 in Figure 19). The -80 dB threshold is satisfied with 10 damped sinusoids for each method (Figure 20). The average CPU times for the MPM, the SS1, and the SS2 are 18.1 s, 25.8 s, and 341.1 s. Since the time for the MPM is about 70.11% of that for the SS1 and 5.30% of that for the SS2, the MPM performs faster than the SS1 and SS2.

5.5 Composite Metallic-Dielectric Sphere

The last example is a composite sphere of radius 0.5 m (Figure 21). The bottom half of the sphere is a perfect conductor, and the top half is a dielectric with $\varepsilon_r = 4$. The back-scattered field has been calculated using WIPL-D from 10-1500 MHz. The incident field arrives along the positive *x*-axis and is *y*-polarized. In this example, the Gaussian window is specified by $\sigma = 0.45$ and $ct_0 = 5.1\sigma$. The inverse-transformed time-domain data is shown in Figure 22.

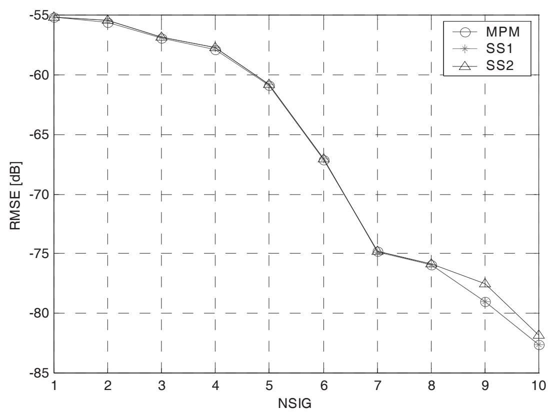

Figure 20. RMSEs of the reconstructed signal for a dielectric sphere.

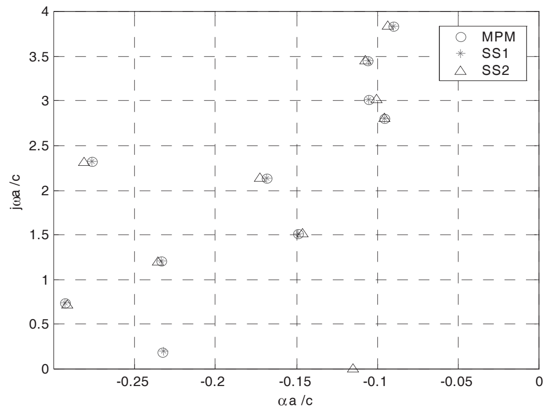

Figure 19. Extracted poles for NSIG = 10 for a dielectric sphere with $\varepsilon_r = 4$ and a 0.5-m radius. The *x*-axis and *y*-axis represent the real and the imaginary values of the pole, normalized with respect to the radius *a* of the sphere, and *c* is the speed of light in free space.

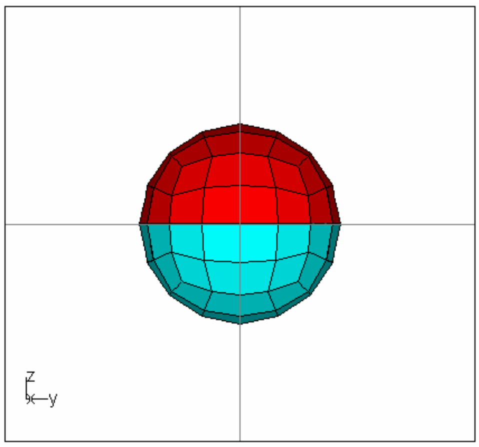

Figure 21. A composite dielectric sphere with $r = 0.5$ m, a perfectly conducting bottom half, and a dielectric top half ($\varepsilon_r = 4$).

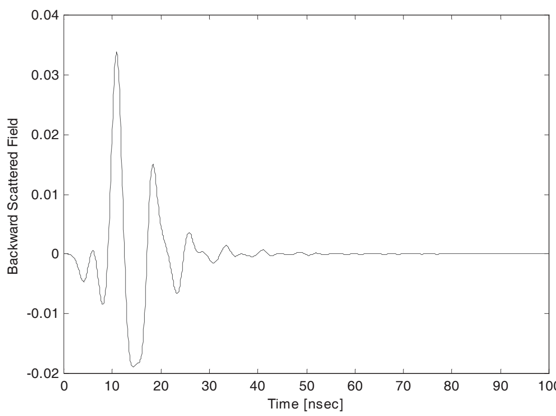

Figure 22. Back-scattered field in the time domain for a composite sphere.

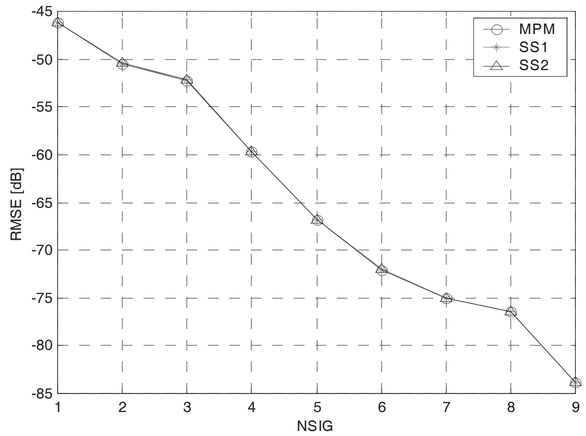

Figure 23. RMSEs of the reconstructed signal for a composite sphere.

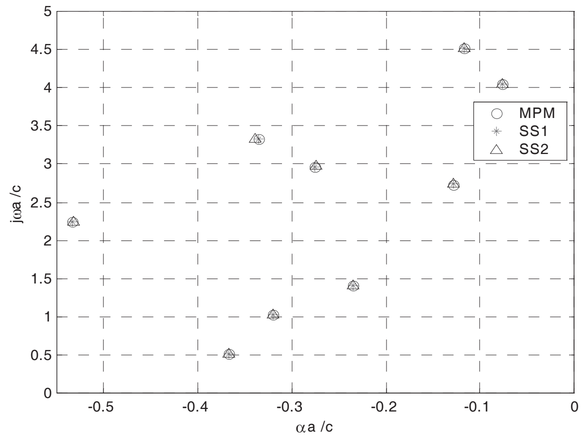

Figure 24. Extracted poles for NSIG = 9 for a composite sphere. The *x*-axis and *y*-axis represent the real and the imaginary values of the pole, normalized with respect to the radius *a* of the composite sphere, and *c* is the speed of light in free space.

The extracted poles are the same for all methods, and the -80 dB threshold is satisfied with 9 damped sinusoids (Figures 23 and 24). The average CPU times for the MPM, the SS1, and the SS2 are 16.95 s, 24.71 s, and 338.31 s. The time for the MPM is about 68.61% of that for the SS1 and 5% of that for the SS2.

6. Conclusions

Three direct-data-domain (DDD) methods, the Matrix Pencil Method (MPM) and two State-Space Approaches (SS1 and SS2), have been fit to simulated scattering data from the WIPL-D electromagnetics code to approximate the corresponding scattered time-domain field by a sum of complex exponentials. Although numerous versions of the State-Space Method [10-12] exist in the literature, the SS2 approach with the Extended Impulse Response Grammian (EIRG) is used to include Markov parameters for comparison with the normal State-Space Method (SS1) and the MPM. Each method has been applied to five simple scattering objects to obtain the poles associated with an object's natural resonance frequencies and the corresponding scattered field. The simulated time-domain fields fall into three basic data types: smooth (cylinder); rapidly fluctuating (wire, conducting sphere, dielectric sphere); and noise-like (composite metallic-dielectric sphere). The extracted complex resonant poles are the same when the data is smooth. However, for pulse-like and rapidly fluctuating data, the SS2 method generated different poles. Furthermore, the three methods have different performances when using noisy data, especially SS2.

Significant differences arise in the CPU times for the three evaluated methods (Table 1). For comparable accuracies, the CPU times of the MPM are about 60-70% of the CPU times of the SS1 and are 4-5% of the CPU times of the SS2. The SS2 takes much longer as a consequence of the assembly time of the respective Hankel matrices, which requires an additional multiplication operation to form each element of the Hankel matrix in using the EIRG. In contrast, the original data is directly used in the MPM, which permits much faster computation. Hence, the MPM is the preferred DDD method, because it accurately determines the natural resonances of the selected scattering objects in the least time.

Model	**MPM [s]**	**SS1 [s]**	**SS2 [s]**	**MPM/ SS1 [%]**	**MPM/ SS2 [%]**
Thin Wire	11.4489	16.8239	224.8235	68.05	5.09
Conducting Sphere	1.3983	2.3284	34.2365	60.05	4.08
Finite Cylinder	19.0647	24.7465	391.4876	71.28	4.87
Dielectric Sphere	18.0860	25.7962	341.0181	70.11	5.30
Composite Sphere	16.9500	24.7059	338.3066	68.61	5.01

Table 1. Average CPU times taken for each model.

It is important to point out that these techniques (MPM, SS1, SS2) are applied directly to the data and not to the covariance matrix, as information on the noise statistics requires additional information that is not available and the noise in an electromagnetic scene is generated typically by undesired signals in the form of a base-line shift in the measurement hardware instead of thermal background noise. In addition, a deterministic model produces a lower Cramer-Rao bound than a stochastic model for the estimation of the parameters of interest. For these reasons, the authors feel that a deterministic approach is at least as applicable, if not more so, to modeling radar returns with stochastic approaches.

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An Ultra-Compact Impulse-Radiating Antenna

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Abstract

We describe the development of an ultra-compact impulse-radiating antenna (UCIRA), intended for space applications in low Earth orbit. Because a UWB (ultra-wideband) antenna was desired for this application, an IRA (impulse-radiating antenna) was selected as the starting point for this development. The standard IRA configuration has a single linear polarization, and has a very narrow beamwidth at high frequencies. A dual-polarization antenna was desired with a larger beamwidth, so we modified the existing design to support dual polarization, and we used a hyperbolic reflector to increase the beamwidth. The antenna also had to survive the harsh space environment, had to be lightweight and very compact for launch, and had to be remotely deployable.

A deployable IRA with dual polarization using a flexible twinline feed has been developed that has very good RF characteristics. Also, the theory for IRAs with hyperbolic reflectors and defocused feeds has been advanced. The UCIRA-2 developed here met many of the requirements.

1. Introduction

We summarize here our efforts to build an Ultra-Compact Impulse Radiating Antenna (UCIRA) for space applications. This may be considered an extension of our earlier work to develop an IRA for space applications fabricated from an inflatable membrane [1]. We subsequently decided that the inflatable technology was only appropriate for very large antennas. For the smaller antennas in which we were interested, a mechanically deployable antenna would be more durable. An example of such an antenna is the commercially available CIRA-2 [2, 3], with a diameter of 1.22 m (48 in.). However, the stowed size of the CIRA-2 was too large for satellite applications. This led to the development of the Ultra-Compact IRA or UCIRA, which is described here.

The UCIRA differs from the CIRA-2 in five respects. First, we reduced the collapsed length from 81 cm (32 in.) in the CIRA to 48 cm (19 in.). This was accomplished by reducing the F/D (focal length / diameter) ratio from 0.4 to 0.3, and by adding a folding joint to each of the 12 radial support rods in the reflector. Second, we defocused the beam with a hyperboloidal reflector, so we could see a larger field of view from low earth orbit (LEO). Third, we configured the antenna to operate with dual polarity. Fourth, we made the antenna automatically deployable with springs and electro-mechanical elements. Fifth, we used materials that could qualify for space applications.

The UCIRA is intended to provide as wide a coverage area as possible from a satellite platform in LEO. In order to receive signals from horizon to horizon, the antenna needs to have a beamwidth of 100° to 120°. Since IRAs are inherently highly directional (narrow beamwidth) at high frequencies, the UCIRA must be defocused using a hyperboloidal reflector instead of a parabolic reflector as described in [4, 5]. We also wanted the bandwidth to be very broad, and a design based on an IRA is well suited for this due to its approximately 2 decades of bandwidth. The CIRA-2, on which the UCIRA is based, is usable from 150 MHz to 10 GHz [3]. In addition, we wanted the antenna to have dual polarity, so twice the information is available from a single antenna.

To study dual polarity IRAs, we experimented with a 46 cm (18 in.) diameter solid aluminum IRA which had two feeds, one for each polarity, vertical and horizontal. This antenna was the IRA-1D. The results of this dual polarity experiment were reported previously in [6].

It has been noted previously by Carl Baum [7] that a hyperboloidal reflector with a circular rim may have a problem in its radiated frequency spectrum on boresight. This occurs at the frequency where the difference in ray path lengths from the center and edge of the reflector is half a wavelength. To address this problem, he proposed using a

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taper in the reflector shape near the edge of the reflector. Our reflector did not use this, because it was not possible to build our fabric hyperboloid with sufficient accuracy for the problem to become apparent. Besides this, our rim has the shape of a 12-sided polygon, instead of a circle.

The environment in LEO is extremely harsh, so we investigated materials that would stand up to the thermal and radiation environment of space. The thermal cycling in LEO is especially severe and can produce drastic thermal gradients within the antenna structure. The temperature range for the environmental test was –60° C to +70° C. For the initial version of the antenna the life expectancy desired is one year. Later versions must be able to function for 5 – 10 years. Due to the short life expectancy of the initial version, deterioration due to atomic oxygen and damage due to micrometeoroids were deemed to be negligible.

The first version of the UCIRA (UCIRA-1) was based on the CIRA-2, but it had a number of changes to make it more compact and automatically deployable. The design of this antenna is described in Section 2 and the results of the RF measurements are given in Section 3. This antenna was then modified in hopes of improving its electrical characteristics. The new version was the UCIRA-1B. This antenna, which had exclusion zones in the reflector where the E field has the wrong polarity [8-10], did not have the improved characteristics expected so the results are omitted from this report. Both versions of the UCIRA-1 had focused parabolic reflectors, and the feed arms were located at ±30° from the vertical, so they did not have dual polarity capability. Instead, they were optimized for high signal strength on boresight [11-14].

The design of the UCIRA-2 is described in Section 4. Although considerable materials research was performed, in most cases the materials used in the UCIRA-2 were similar to those used in previous versions. However, there were several important exceptions. The Ni/Cu plated polyester fabric used for the reflector on the CIRA-2 and UCIRA-1 was replaced with Ni/Ag plated rip-stop nylon. The nickel-over-silver plating maintains its conductivity much better than the nickel-over-copper plating. The aluminum parts were plated with Tuframâ to harden the surface and reduce friction where required. Also, the nitrogen-filled gas spring used on the UCIRA-1 was replaced with standard stainless steel springs, because gas springs lose their pressure at temperatures below –40°C. One of the major improvements was the replacement of the manually operated release pin with electrically operated release devices to provide remote activation of the deployment mechanism. A pin puller and an Ejector Release Mechanism (ERM) are used for the two-step deployment of the UCIRA-2.

In Sections 5 and 6 we provide the results of the RF measurements made on the UCIRA-2 in two different configurations. First we tested the antenna in the standard single-polarity mode and then we tested it in the dual polarity mode.

We begin now with the design of the UCIRA-1.

2. UCIRA-1 Design

We show the UCIRA-1 in the collapsed or stowed configuration in Figure 1. By using a single hinge point to fold the stays to the outside and using an F/D ratio of 0.3 we were able to fold the IRA down to a length less than the required 0.483 m (19 in.). The main body of the collapsed antenna is just under 48 cm (19 in.) long and 18 cm (7 in.) in diameter. An aluminum ring is used to hold the tips of the stays in place. This ring does not work very well so a cord is used to help hold the folded reflector in place. The aluminum ring is not used on later versions.

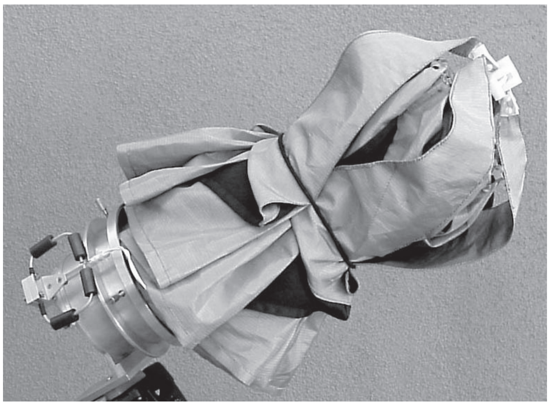

Figure 1. UCIRA-1 in stowed configuration

In Figure 2 we show the UCIRA-1 in the fully open position. The diameter of the reflector is 1.22 m (48 inches). The feed arms for this version have the outer edge inline with the rim of the dish (non-floppy) and are at the more optimum ±30° from the vertical [3], [8-14] so this version cannot be used in dual polarity mode. The feed arms were accidentally sewn slightly long so there is a problem keeping

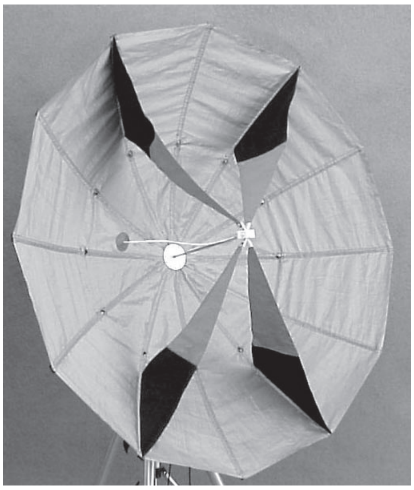

Figure 2. UCIRA-1 in deployed configuration.

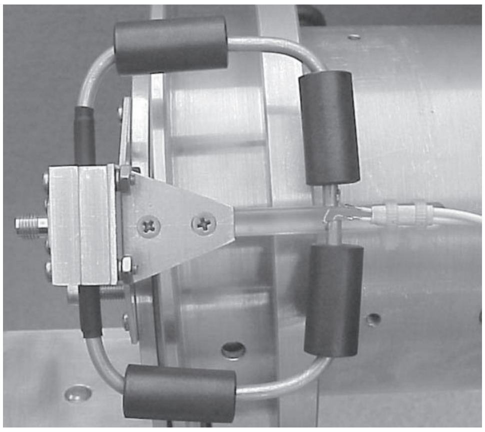

Figure 3. UCIRA-1 splitter/balun.

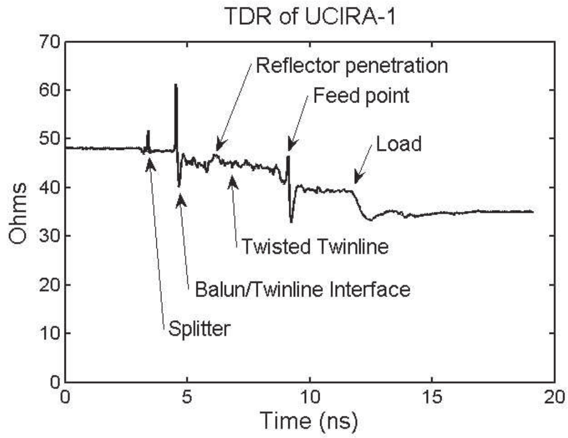

Figure 5. TDR of the UCIRA-1.

the feed arms tight. Part of the problem is, also, the very small diameter stays that were used for weight reduction and the higher than expected force required to open the antenna. The next size larger carbon composite rods will be used in the future to provide more stiffness to better support the reflector.

In Figure 3 the splitter balun can be seen attached to the side of the can that houses the deployment mechanism. The splitter connects the 50 Ω input to two 100 Ω coax cables in parallel. The ferrite beads prevent currents on the outside of the cables, which tend to short out the feed point. The ends of these cables are connected in series to provide the 200 Ω feed for the twinline [15]. The twinline is made from two strands of 26 AWG Teflon insulated wire. To increase the spacing of the conductors, the insulation from 18 AWG wire was placed over the 26 AWG wire. The computed impedance of this combination is 186 Ω, which is almost exactly what we measured from the TDR of the cable. The twinline passes through a hole in the reflector and connects to the feed arms at the focus of the parabola. The twinline is approximately 0.56 m (22 in.) long and can be seen in Figure 3 as well as in Figure 2. The attenuation of the balun/twinline combination is shown in Figure 4. The attenuation is below 6 dB out to 10 GHz.

The antenna is deployed manually by pulling a pin on the side of the deployment mechanism to release a cam that is pushed forward by a high pressure gas spring (nitrogen filled cylinder). Small levers attached to the ends of the stays are rotated by the cam to open the reflector. The gas spring not only provides enough force to move the cam, but provides the force required to hold the reflector open. A damper is used to slow the cam so that the stays open at a rate that will not cause damage to the antenna. The damper operates by controlling the flow of air from the inside of the deployment mechanism. The flow is controlled using a needle valve in the back surface of the mechanism. This type of damper cannot be used in space and is replaced with a crushable medium in later versions of the antenna.

3. UCIRA-1 RF Measurements

We now present the antenna measurements for the UCIRA-1 made at 20 m. The TDR of the UCIRA-1 is presented in Figure 5. The greatest mismatches and, therefore, the largest reflections occur at the transitions at each end of the twinline.

In Figure 6 we see that the impulse response has a FWHM of 67 ps, which is better than we expected, since it

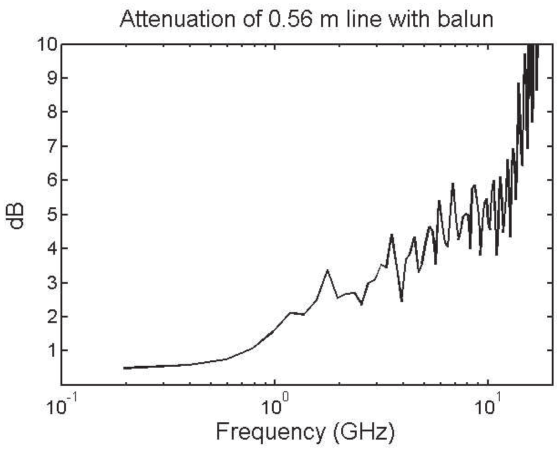

Figure 4. Attenuation of twinline and balun.

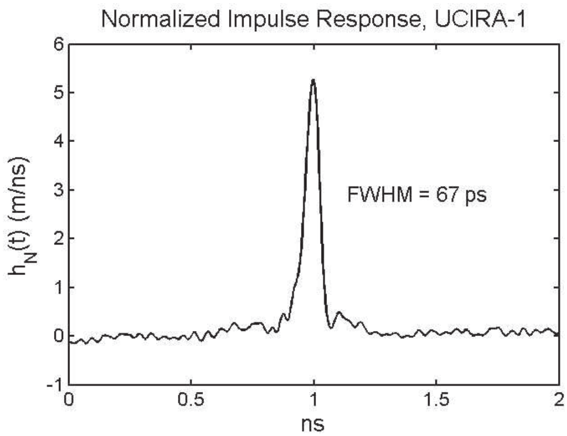

Figure 6. Normalized impulse response of the UCIRA-1.

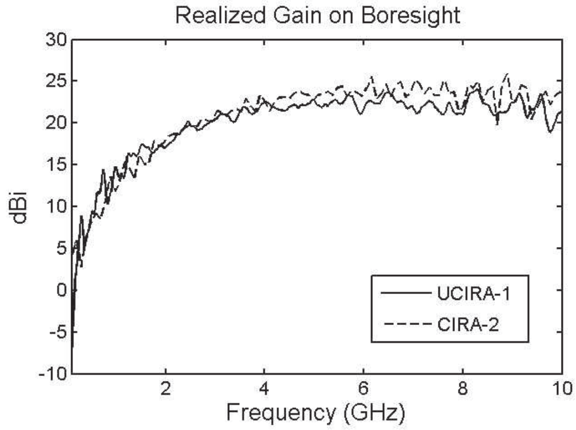

Figure 7. Realized gain of the UCIRA-1 and CIRA-2.

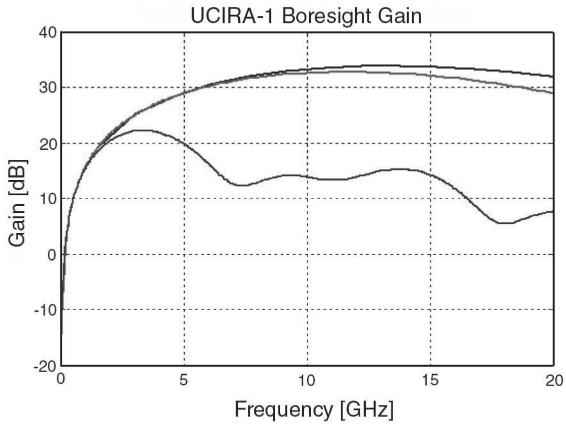

Figure 8. Theoretical gain of UCIRA-1 for defocus parameters of f_o = 0°, 1.5°, and 10° (top to bottom).

is 6 ps better than the commercial CIRA-2 [2, 3]. The CIRA-2 has a standard feed with two coaxial cables that extend to the feed point; whereas the UCIRA-1 has a twinline feed that we expected would be less efficient and more lossy at high frequencies. The CIRA-2 is similar to the UCIRA but it has an *F*/*D* of 0.4 instead of 0.3. Thus, we conclude that the twinline feed works much better than we expected.

The normalized impulse response, *hN*(*t*), mentioned above describes an antenna's performance in both transmission and reception. This quantity is the normalized impulse response in reception and the normalized step response in transmission. In this format, we have the reception and transmission equations as [16]

$$\frac{V_{rec}(t)}{\sqrt{50\ \Omega}} = h_N(t) \frac{E_{inc}(t)}{\sqrt{377\ \Omega}}$$

$$\frac{E_{rad}(t)}{\sqrt{377\ \Omega}} = \frac{1}{2\pi cr}\ h_N(t) \frac{dV_{src}(t)/dt}{\sqrt{50\ \Omega}}$$

where *Vrec*(*t*) is the received voltage into a 50 Ω load or oscilloscope, and *Vsrc*(*t*) is the source voltage as measured into a 50 Ω load or oscilloscope. Furthermore, *Einc*(*t*) is the incident electric field, *Erad*(*t*) is the radiated electric field, *r* is the distance away from the antenna, *c* is the speed of light in free space, and "$\circ$" is the convolution operator. Note that the above expressions refer by default to the dominant polarization on boresight, but they are easily extended to multiple angles and polarizations. Note also that *hN*(*t*) has units of meters per second.

In Figure 7 we show the realized gain (effective gain) of the antenna. The CIRA-2 data is included in the figure for comparison. We see that the effective gains for the two antennas are about the same up to 10 GHz. The losses due to the twisted twinline are almost negligible. In Figure 8 we show the theoretical gain for the UCIRA based on work by Scott Tyo [4, 5]. The three lines correspond to defocus parameters ϕ_O = 0°, 1.5°, and 10°. The defocusing parameters will be discussed later. Since the UCIRA-1 has a parabolic reflector, it corresponds to the top line, ϕ_O = 0°. The measured gain for the UCIRA-1 is considerably lower than the theoretical value. This is due in part to the dispersion of the reflector, since the reflector is made from 12 panels and therefore is not a true paraboloid of revolution. It is interesting to note the reduction in the gain when a hyperbolic reflector is used to increase the beamwidth as can be seen in Figure 8.

In addition to the copol gain on boresight shown above we also measured the crosspol gain on boresight. The average crosspol rejection is approximately 20 dB. The antenna pattern measurements in the H and E planes showed some sidelobes as is characteristic of the narrow beamwidth of an IRA, although it has been shown that the side lobes are reduced when the feed arms are located at the more optimal ±30° from vertical [13].

4. UCIRA-2 Design

The design of the UCIRA required considerable research into materials suitable for use in a LEO space environment. The harsh space environment includes long duration vacuum, particle radiation, solar radiation (UV), temperature extremes, rapid thermal cycling, atomic oxygen, and micrometeoroid impact. We gained considerable information on materials and deployable device design from [17]. In the past we have used aluminum and stainless steel for most of the mechanical parts, carbon composite or fiberglass rods for the stays, Ni/Cu plated rip-stop nylon for the feed arms and reflector, and polypyrrole treated polyester for the load resistors. Although we used some of the same or similar materials on the UCIRA-2, there were a number of improvements based on our research and thermal testing.

The Ni/Cu plated nylon fabric used on the UCIRA-1 was replaced with a different rip-stop nylon (94EN) that is Ni/Ag plated that does not loose conductivity when creased.

Figure 9. UCIRA-2 in stowed configuration.

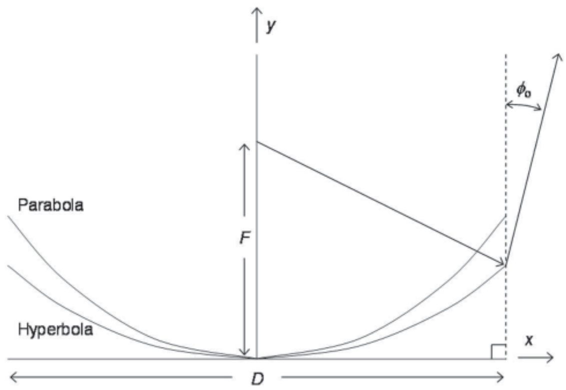

Figure 11. The conversion of a paraboloidal reflector to a hyperboloidal reflector.

We have some concern about the use of nylon in space; however, it appears to work better than expected so we used this material for the UCIRA-2. We also continued to use the polypyrrole treated polyester for the load resistors as we have done in the past. This material has a surface resistance of approximately 200 Ω/sq so it is easy to obtain the correct load resistance.

For the ribs or stays that support the reflector we used graphite reinforced composite rods. The hinges in the stays are aluminum with stainless steel torsion springs.

The UCIRA-2 is shown in Figure 9 in the stowed configuration and in the fully deployed configuration in Figure 10. The UCIRA-2 has a hyperboloidal reflector to broaden the beamwidth and has dual polarization capability. The hyperboloidal shape should increase the beamwidth by about 20° [4, 5]. The diameter of the reflector is 1.22 m (48 inches) and the F/D is 0.3 as with the UCIRA-1 and 1B. The feed arms have the outer edge inline with the rim of the dish (non-floppy) and are evenly spaced around the reflector to facilitate the dual-polarized feed. The antenna weighs approximately 2.6 kg (5.75 lb.). Most of the mass is in the deployment mechanism. This mass could be reduced somewhat by additional mechanical analysis and reducing the thickness of parts where possible.

Figure 10. UCIRA-2 in deployed configuration

Now we will describe the modification required to broaden the beamwidth of the UCIRA, we defocus the aperture by converting the paraboloidal reflector into a hyperboloid. In doing so, we must maintain the same reflector diameter and focal length. We specify an angle, ϕ_O, which is the angle at which the extreme ray at the edge of the reflector deviates from the focal direction (y), as shown in Figure 11. When $\phi_O = 0$, the hyperboloid reverts back to the paraboloid.

It is unclear how the parameter ϕ_O affects the beamwidth. At extremely high frequencies, the beamwidth is $2\phi_O$, which is the optical limit. In practice, of course, this is never achieved. As proof of this, a focused paraboloid with $\phi_O = 0$ does not have a beamwidth of 0° at any frequency. At lower frequencies, a reasonable guess is that the beamwidth will broaden the beamwidth by an extra $2\phi_O$ beyond the beamwidth of the focused (paraboloidal) case. J. Scott Tyo has investigated this in somewhat more detail in [4, 5]

We revisited several issues concerning the mechanical deployment system used on the UCIRA-1 and made several changes. First we found that the manual release pin on the UCIRA-1 was much too difficult to pull. An automatic pin puller capable of holding the cam in place during launch and then releasing the cam on command was out of the question. Therefore, we replaced the release pin with an Ejector Release Mechanism (ERM) from TiNi Aerospace, Inc. Release is accomplished on command (9 VDC at 5 A for 20 ms), by retracting five detent balls that hold a coupler to the actuator, thereby ejecting the coupler and releasing the cam to which it is attached.

Next, we replaced the gas spring used in the UCIRA-1 with 9 stainless steel conventional springs arranged in a circle around the ERM. The gas spring had the advantage of small size and nearly constant force over the length of the stroke. However, we learned that gas springs cannot be used below -40°C because they tend to lose the high pressure nitrogen charge at such low temperatures. The 9 conventional springs have a total force of 2.67 kN (600 lb.) in the compressed or launch configuration and 1.33 kN (300 lb.)

in the deployed configuration. This provides sufficient force to fully open the reflector with the recommended safety factor [17]. At one point in the development we had planned to use a small servo motor to deploy the reflector; however, these motors are normally custom designed for a particular application, so no adequate off-the-shelf motor was found. An additional problem is that a small motor would require a gear-type speed reducer with a very high mechanical advantage to provide the force required to hold the reflector open. Springs seemed to be the best alternative for the present design but since the antenna opens much faster than we would like, a motor drive may still be required in the future. One problem with the motor drive is that power is needed to drive the motor. This adds weight and/or complexity to the system. The Ti/Ni actuators can be triggered with a 9 V battery.

The deployment mechanism has four stop pin assemblies that keep the cam from rotating and lock the cam in the forward position after deployment. Since we decided to use springs rather than a much more costly and complex motor system, we were forced to include a damping system. This system uses an aluminum honeycomb material, which is crushed to control the opening velocity of the cam and the sudden stop and consequent vibration at the end of the cam's travel.

One end of the stay adaptors or pivots that position the reflector ribs slides on the front surface of the cam as it moves forward. This rotates the stay adaptors and moves the stays to the open position. The surfaces of the moving aluminum parts are coated with Tufram® by General Magnaplate. This coating creates a steel-hard, dry-lubricated surface on aluminum that reduces abrasion and corrosion and resists wear and galling. The dry-lubricated surfaces greatly reduce the force required to overcome friction between the various surfaces.

A rear view of the deployment mechanism is shown in Figure 12. The actuator ERM is located in the center of the back plate and restrains the cam in the stowed

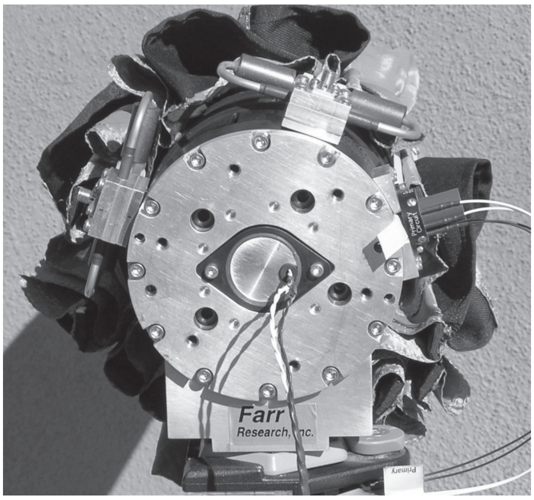

Figure 12. UCIRA-2 deployment mechanism (rear).

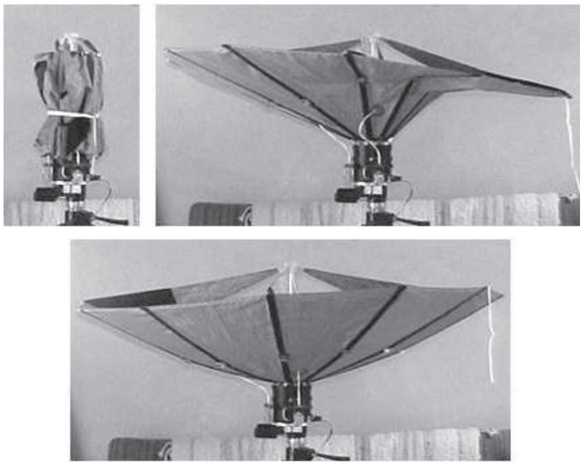

Figure 13. UCIRA-2 in stowed, partially open, and fully deployed configurations.

configuration. There are four holes around the ERM for attaching the device that compresses the springs to put the UCIRA-2 in stowed configuration. Four rods thread into the back side of the cam through these holes to pull the cam back against the back plate while the coupler on the ERM is attached to hold the cam in place. The pin puller is located to the right and holds the end of a strap that restrains the reflector stays in the stowed configuration. Figure 12 also shows the two splitter/baluns (left and top) required for the dual polarity operation of the antenna.

For proper deployment of the UCIRA we had to determine the correct amount of crushable honeycomb material to use to retard the cam, which opens the reflector. We first tried a full circular section of the material and found that the cam was stopped immediately by the honeycomb. After several experiments we found that two sections of a little over 1/8 circle each would allow the reflector to open fully. During these experiments the stay adapters were damaged and had to be replaced. The original stay adapters were made of aluminum and had a very thin cross section at the pivot point. The new stay adapters were made of stainless steel and had a more substantial cross section at the pivot point. The ends of the stay adapters are highly polished to reduce friction where they slide on the front of the cam.

It was found during the deployment tests that the bending moment at the end of the stay adapters tends to over-stress the ends of the stays and several were broken during the tests. Longer stay adapters with deeper holes to support the ends of the stays would reduce this problem and improve the shape of the reflector.

The UCIRA-2 was successfully deployed several times while being video recorded digitally. Three still pictures taken from the video showing the antenna in the stowed, partially open, and fully deployed states are shown in Figure 13. In the first picture the strap that holds the upper section of the stays in the folded position is shown (white). The end of this strap is retained by the pin puller, which is activated first in the deployment sequence. Releasing the strap allows the springs in the stay hinges to partially open the reflector as seen in the second picture. In this photo we see that the right side of the reflector did not open as fully as the left side. However, this did not interfere with the full deployment of the antenna as shown in the third picture. The rim was not as level or even as we would like after this experiment so several slightly damaged stays were replaced before the RF testing described in the next two sections. Also, the interface between the resistive and conductive sections was re-sewn on each of the four feed arms to improve the electrical connection between these sections.

As mentioned earlier, a honeycomb material is used to retard the action of the cam in an attempt to control the speed at which the antenna opens. However, the small sections (about 1/8 circle each) that are required to allow the reflector to open fully also allow the antenna to open very fast. This rapid deployment may produce such a dynamic stress on a space vehicle as to cause problems with the stabilization and orientation system.

5. UCIRA-2 RF Measurements in Single-Polarity Configuration

The RF measurements were made using our newly developed Portable Automated Time-domain Antenna Range (*PATAR*™) System. The system includes a fast pulser, a fast digital sampling oscilloscope, two calibrated TEM field sensors, an elevation/azimuth antenna positioner, a computer controller, and software for system control, data acquisition, and data processing. The fast pulser is a PSPL 4015C with a rise time of approximately 20 ps. The pulser drives one of the TEM sensors to form the transmit portion of the antenna range. The oscilloscope is a Tektronix TDS8000 with an 80E01 sampling head. The UCIRA-2 is connected to the TDS8000 to form the receive section of the system. The UCIRA-2 is mounted on the *PATAR*™ antenna positioner, which has a non-conductive mast to reduce interference with the antenna. The distance between the apertures was 20 m.

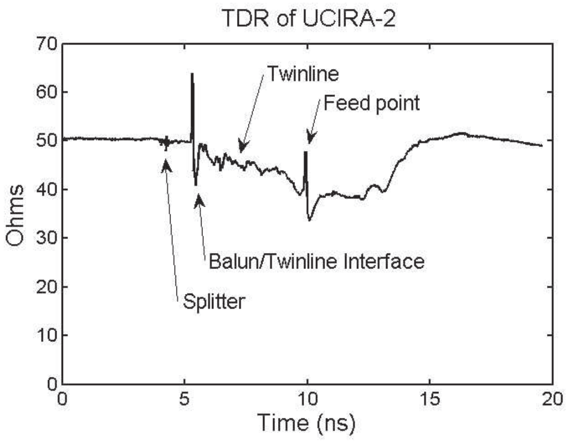

Figure 14. TDR of the single polar UCIRA-2.

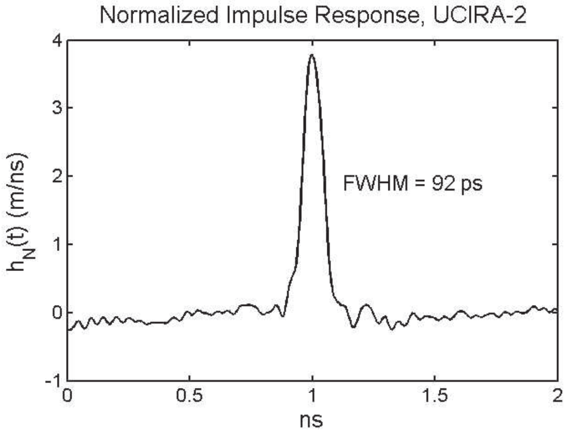

Figure 15. Normalized impulse response of the UCIRA-2.

In Figure 14, we show the TDR of the UCIRA-2 in the standard (single-polarity) IRA configuration [15]. The various parts of the feed are shown in the figure. The discontinuity at the balun/twinline interface is greater than we would like and it may be possible to improve this interface.

We show the normalized impulse response in Figure 15. The impulse response has a reasonable shape, but the FWHM is greater than we would like. This reduces the gain at high frequencies. The depth of the reflector varies about 4 cm from one side to the other which is not desirable. This is due in part to repairs that had to be made to the feed arms. The required overlap of 1 cm between the conductive and resistive sections of the feed arms was not maintained as accurately as we would like so the overall length of the feed arms varies a little.

In Figure 16 we show the gain as a function of frequency for the UCIRA-2 in copol and crosspol. The gain rolls off some between 4 GHz and 10 GHz but the peak gain is comparable to that of the UCIRA-1 and 1B. The gain of the CIRA-2 [2, 3] is significantly better between 5 and 10 GHz because its reflector is a paraboloid instead of a hyperboloid.

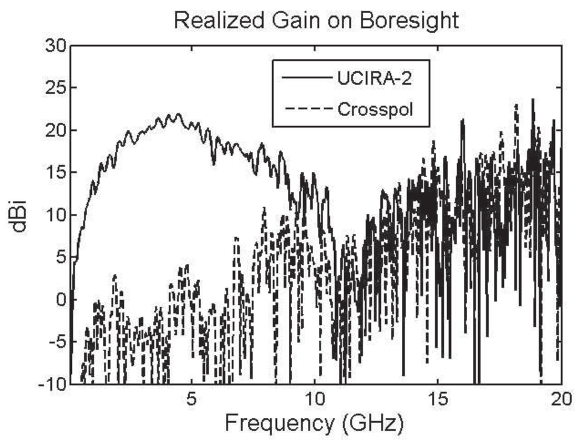

Figure 16. Gain of the UCIRA-2 in copol and crosspol configuration.

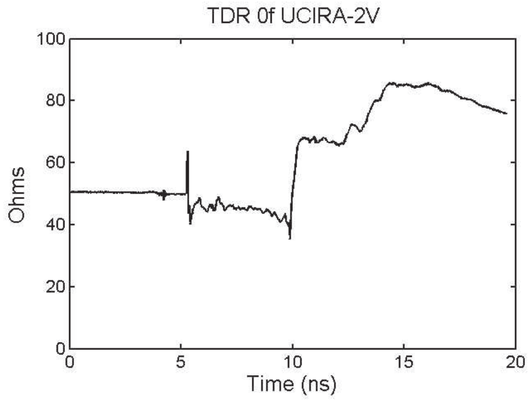

Figure 17. TDR of the dual polar UCIRA-2 (Vertical).

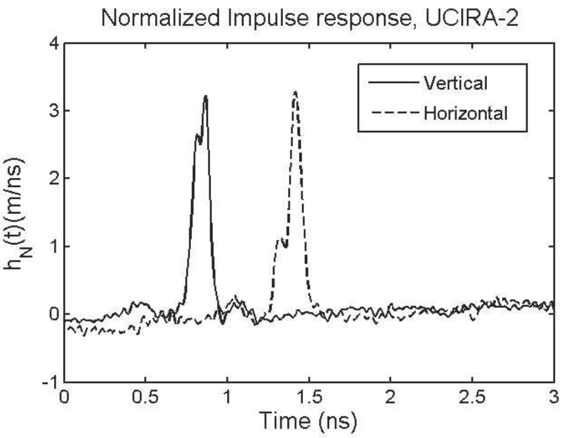

Figure 18. Normalized impulse responses of the UCIRA-2.

By measuring the antenna pattern of the UCIRA-2 on the major planes, we found that the beamwidth is approximately 10-12°. The design beamwidth is 20°greater than for a parabolic reflector, so it appears that we did not meet this goal; however, the shape of the antenna is not quite as accurate as we would like. The fabric reflector is approximately 4.3 cm (1.7 inches) deeper than desired and the distance from the feed point to the reflector is not as accurate as we would like. The reflector should be somewhat flatter than it is. This is in spite of several modifications that have improved the shape to some extent. It is very difficult to compensate for the stretch in the fabric and various effects of the sewing operation.

6. UCIRA-2 RF Measurements in Dual Polarity Configuration

Next, we provide the results of measurements made on the UCIRA-2 in dual polarity mode. In Figure 17 we see that the impedance jumps at the feed point where the 200 Ω twinline connects to the 400 Ω feed arms. The impedance should jump from 50 Ω to 100 Ω in the TDR at this point due to the effect of the balun. However, in this case the jump is not that great. This is perhaps due to losses in the twinline that reduce the reflected voltage, so the full effect of the impedance mismatch is not seen in the TDR.

We present the normalized impulse response for both channels of the UCIRA-2 in Figure 18. The shape of the impulse response is not ideal and the FWHM is somewhat high (108 ps for the vertical channel). This leads to reduced gain at high frequencies as seen in Figure 19. In Figure 20 we show the theoretical gain for the UCIRA-2 in dual polarity mode based on work by Scott Tyo [4, 5]. The gain of the vertical channel of the UCIRA-2 agrees reasonably well with the predictions, but it falls off more at 10 GHz. It is interesting that the reduced gain above about 5 GHz is due to defocusing the reflector and not primarily due to antenna assembly problems as is sometimes the case. Ideally the gain of the horizontal channel should be the same as that of the vertical channel; however, as can be seen in Figure 19 it is quite different. The differences are due to variations in the antenna especially at the feed point. At the feed point, two of the wires from separate twinline feeds must cross to be connected to the tips of the feed arms in the proper configuration. This requires one wire to be in front of the other, so the wiring cannot be totally identical for the two feeds.

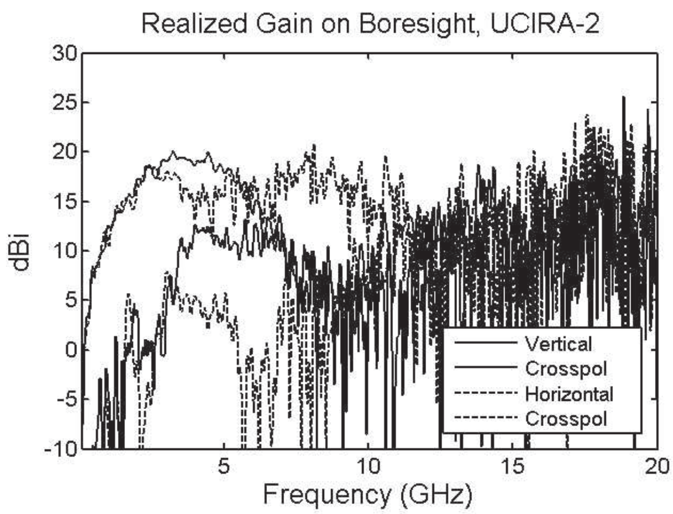

Figure 19. Realized gains of the dual polar UCIRA-2.

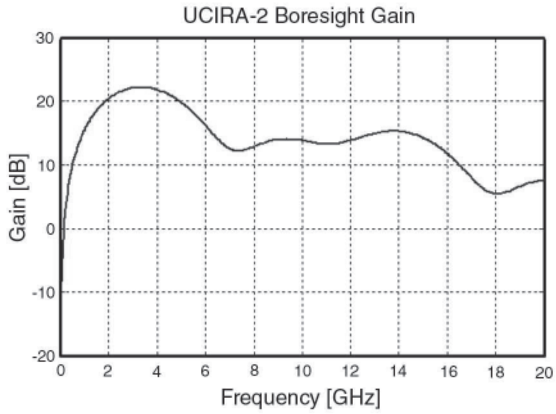

Figure 20. Theoretical gain of UCIRA-2.

One of our greatest challenges on this project has been the construction of the reflector so that it accurately maintains the desired hyperbolic shape. A considerable amount of dispersion results when the path lengths of various rays vary over the surface of the reflector. It is difficult to keep the weight of the antenna minimal, keep the force required to open the antenna reasonable and still have the stays strong enough to support the fabric reflector in the correct shape. It is also difficult to accurately sew the fabric. Other construction methods and materials may be available, but for this mechanical deployment scheme a very flexible material such as the conductive rip-stop nylon is required. Thin plastic sheets would probably have a tendency to crack and/or tear during deployment or not lie flat after deployment.

Measurements of the antenna patterns for both channels in the E and H planes show that the beamwidth in both planes is approximately 12° - 14°. This is approximately the same beamwidth obtained in the standard configuration. This is not surprising since the reflector has not changed. As mentioned before, the design beamwidth was 20° so we are somewhat disappointed with this result.

By comparing Figure 19 with Figure 16, we see that the gain of the antenna in the dual polarity mode is about 2-3 dB less than it is in the standard single feed mode. This relatively small loss, due largely to the impedance mismatch at the feed point, is a small price to pay for adding the dual polarity capability to the antenna.

7. Conclusions

We built three versions of the Ultra-Compact Impulse Radiating Antenna, or UCIRA, which was intended for space applications. The first version, the UCIRA-1, had electrical performance that was only slightly less than that of our commercial CIRA-2. This was a remarkable result, because the UCIRA-1 had a twinline feed instead of the coaxial cable feed in the CIRA-2. In its collapsed position, the UCIRA-1 was smaller than our commercial CIRA, but a manual operation was required to deploy it. In the UCIRA-1B, we attempted to improve the boresight gain by removing the negatively contributing portion of the reflector. This resulted in performance that was less than that of the UCIRA-1, because the reflector shape came out worse than before.

In the final version of the UCIRA, the UCIRA-2, we introduced a number of improvements. We incorporated an automatic deployment mechanism, we defocused the aperture to broaden the beam, we allowed for dual polarization, and we used materials that could be qualified for space operation. Since the feed arms were positioned at equal 90-degree increments around the edge of the reflector, we could feed the antenna either as a single-polarization antenna with good impedance match, or as a dual polarization, dual channel antenna with a 2:1 impedance mismatch. When configured as a single-polarization antenna, the gain was considerably less than that of our commercial CIRA-2, because the reflector was defocused into a hyperboloid. When configured as a dual channel antenna, each channel performed well only up to 4-5 GHz, which is sufficient for many applications.

After studying the various materials that could be used in space applications, the materials used in the UCIRA-2 were very similar to or the same as those used for earlier collapsible antennas. We found a better conductive fabric for the reflector, and we found that nylon should be a satisfactory fabric for this application. The Tuframâ surface treatment on the aluminum was a big improvement. This process forms a heavy aluminum oxide coating on the aluminum and then a polymer is infused into the surface to form a self-lubricating surface.

The development of the balun/twinline feed was a major success, since the feed for a deployable antenna must be very flexible. The attenuation measured for this type of feed was low enough over the frequencies of interest that it could be used for the satellite application considered here.

Because of a bug in our ERM, we were able to complete only a portion of the environmental testing. A slight modification to the ERM actuator will make it possible to complete the testing should the need arise later.

There are several minor mechanical modifications that will improve the deployment of the reflector. Using composite rods for the stays with a slightly larger diameter should stretch the reflector tighter to obtain a better shape. Longer stay adapters should be used to reduce the forces on the ends of the stays. A method of fabricating the reflector other than sewing may provide a more accurate reflector.

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Triennial Reports Commissions

COMMISSION A

This triennium report was prepared by Dr. Q. Balzano, Commission A Chair 2002-2005.

In the triennium 2003-2005 Commission A has been active in support of the Scientific Committee on Telecommunications (SCT), of the Solar Power Satellite Project and in preparing the sessions of the 2005 General Assembly in New Delhi.

In addition to session KA, session KE was given technical support.

Specific suggestions to the STC regarded the possibility of unexpected interference phenomena due to the proliferation of electronic devices for communication and health maintenance. The support for the SPS program consisted in preparing a sufficiently detailed test program for the large antenna of the SPS.

A substantial effort was dedicated to inviting two top experts in Ultra Wide Band (UWB) Technology to give a general lecture and a paper on UWB signaling at the 2005 GA. Profs.H. Bertoni (N.Y. Poly), W. Stark (U.of Michigan), Broderson (Berkley) and Milstein (USC) were contacted and invited to New Delhi. Not one of these distinguished scientists was available.

Liaisons were maintained with Commission K, by attending the meetings organized by Commission K at the BEMS Symposia of 2004 and 2005.

The Radio Science Bulletin

Two papers are in preparation for the Radio Science Bulletin:

I. I. Smolyaninov, Q. Balzano, C. Davis " A Review of Plasmon Polariton Excitation in Doubly Periodic Array of Holes"
II. K. Foster and Q. Balzano" A New Analytical Method for the Computation of SAR from Coated Wire Antennas immersed in Tissue".

Sponsored Scientific Meetings

The following meetings were sponsored by Commission A:

1) JINA 2002, Nice, France 12-14 November 2002
2) EMC Zurich 2003, Zurich, Switzerland 18-20 February 2003
3) Telecom 2003&JFMMA, Marrakech, Morocco 15-17 October 2003
4) WARS04 (Workshop on Application of Radio Science) Conference 2004, Hobart, Tasmania, Australia, 18-20 February 2004
5) International NIR Workshop and Symposium, ICNIR, URSI(K)/ WHO Symposium, Seville, Spain, 20-24 May 2004
6) EMC Wroclaw 2004, Wroclaw, Poland, 29 June- 1 July 2004
7) AP-RASC 04: 2004 Asia-Pacific Radio Conference, Beijing, China,20-23 August 2004
8) Radar 2004, Toulouse, France, 19-21 February 2005
9) EMC Zurich, 2005, Zurich, Switzerland 15-17 February 2005
10) VI International Symposium on Electromagnetic Compatibility and Electromagnetic Ecology, St. Petersburg, Russia, 21-24 June, 2005
11) International Workshop on Electromagnetic Fields at the Workplace, Warsaw, Poland, 5-7 September 2005.

Budget

One third of the budget was expended in the support of meeting and symposia.

The rest was kept in reserve to fund the attendance of two speakers on UWB at the GA 2005 in New Delhi.

COMMISSION B

This triennium report was prepared by Professor M. Ando, Commission B Chair 2002-2005.

Introduction

The officers of Commission B during the triennium 2002 - 2005 have been Prof. Makoto Ando, Japan, Chair, and Prof. Lot Shafai, Canada, Vice-Chair. Immediate Past Chair has been Prof. Staffan Ström. The Chair, Vice-Chair and Immediate Past Chair have formed " the Commission B Executive Committee ", in which important Commission B matters have been discussed. In addition, for election of the next Commission vice-chair, "the Commission B Search Committee(CBSC)" formed by the current Chair, two immediate Past Chairs. makes sure that enough candidates are being nominated. One more important organization "the Commission B Technical Advisory Board (B-TAB)" established in 2002 has worked actively for the technical program in 2004 Commission B EMT-Symposium in Pisa and 2005 General Assembly in New Delhi. To fulfil its role in URSI properly, Commission B relies on the dedicated and enthusiastic support of a large number of Commission B colleagues as described below in this report and its enclosures.

The 2004 International Symposium on Electromagnetic Theory (2004 EMTS)

Organization

The 2004 URSI International Symposium on Electromagnetic Theory (EMT-S) was held in Pisa, Italy, May 23-27, 2004. It is hosted by the Italian Member Committee of URSI and is organized by a Local Organizing Committee (LOC) at the University of Pisa, in collaboration with the Italian Electromagnetic Society (SIEm).

This triennial event is one of the major activities of URSI Commission B and is the 18th in the long history since the 1st in Toronto 1953. The most recent past Symposia in this series were held in Victoria, Canada (2001) and Thessaloniki, Greece (1998). The preparation of the 2004 EMT-S in Pisa was initiated upon the decision in the business meeting at the 2002 URSI General assembly. Thanks to the intensive collaboration from the Italian national committee of URSI and LOC chaired by Prof. Giuliano Manara and the Technical Program Committee (TPC), consisting of 40 members from 16 countries, we completed preparations for a very attractive and rich symposium. Two-times submission (Abstract and then final paper) is changed to one-time submission (Paper in 3-pages camera-ready format) from 2004 EMTS.

Technical Program

The scope of the Symposium covers all areas of electromagnetic theory and its applications. One of the key features of the Symposium was a series of plenary sessions held every morning entitled: “Perspectives into the History and Development of Electromagnetics —Past Present and Future”, which has always been a special characteristic of EMT-S. A total of 26 topics convened by 50 authorities worldwide as well as 37 regular ones were prepared in the call for papers. As a result, we have received 464 submissions and selected 421 papers. We have put together a rich set of sessions, that is, 62 oral sessions with 6 papers, 4 plenary sessions and 1 poster session. These include progress in traditional topics such as electromagnetic theory, guided waves, scattering and diffraction and the latest topics such as metamaterials, ultra wide band signals and practical aspects of ground penetrating radars, etc. Following special topics were prepared.

- Artificial Magnetic, Soft and Hard Surfaces and other Complex Surfaces
- Ground penetrating radars: EM modeling, antennas, imaging and inversion
- Homogenization of electromagnetic material parameters
- Hybrid techniques for large problems
- Metamaterials
- Radiation and Leakage effects in open planar structures
- RF aspects of MIMO antenna systems
- Space Solar Power Systems (Inter Commission WG in URSI)
- The role of electromagnetism in micro- and nanotechnologies
- Time-reversal methods
- UWB radio systems

In the Commission B business meeting in 2001 EMTS, it was noted that 221 attendance and 215 presented papers in 28 Sessions in 2001 EMTS were lower than those(470 submission and 290 presented) of the previous 1999 EMTS in Thessaloniki, Greece. This situation gave Commission B reason to re-consider its activities, in particular its conference activities; Commission B Technical Advisory Board (B-TAB) was established in this framework. The statistics in 2004 EMT-S were almost equal or larger than those for 1999 EMTS, which were through the efforts of LOC, TPC and B-TAB. The report on the 2004 EMTS by Giuliano Manara will contains more details.

Young Scientist Award

Commission B Young Scientist Award were prepared for supporting young scientists under 36 years old to attend the 2004 EMTS. Award recipients will receive free Symposium registration and financial support to defray the cost of modest board and lodging during the period of the Symposium. Limited funds will be available to assist in payment of part of the cost of round trip travel of reward recipients from developing countries. As before, Commission B spends essentially all of its grant from URSI on Young Scientist Awards at the EMTSs. Thanks to the efforts by LOC, total of 26 Young Scientist were Awarded. The total cost for these awards were about 27000 EURO and is jointly covered by the LOC(2/3) and Commission B(1/3). With an interesting scientific program arranged by TPC, with an excellent conference organization and with support from the Italian national committee and LOC, 2004 Commission B EMTS resulted in great success.

Special Section of 2004 PISA EMT-S in Radio Science published in Fall 2005

As on several previous occasions, Radio Science has kindly agreed to publish a ‘ Special Section ‘ containing selected papers based on presentations at the 2004 EMTS. Prof. Akira Ishimaru, Univ. of Washington, has again agreed to serve as Co-Editor for this Special Section, together with Prof. Makoto Ando, the Commission B Chair. It is expected to appear in a Radio Science issue around November-December issue of 2005.

This special section of *Radio Science* is comprised of 18 (tentative) full-length papers selected from 391 papers presented at the meeting. (For 2001, about 25 papers were accepted and appeared in the Nov.-Dec. issue of Radio Science.) Papers considered for inclusion in this special section were recommended by session chairs or technical program committee members. From these recommendations, the final selection of papers was made by the Special Section Editors, and authors were then invited to submit manuscripts. In keeping with the usual Radio Science policy, all papers were reviewed before the final decisions were made for publication. We wish to express our appreciation to the local organizing committee, the technical program committee and the session chairs for their advice and recommendations. We also thank the reviewers for their time and efforts and the authors for their timely work which contributed greatly to the success of the Symposium and of this special section of *Radio Science*.

The venues for the symposia and special sections of Radio Science which contain selected papers are the following:

1953 Montreal, Quebec, Canada (microwave optics)
1954 Ann Arbor, Michigan
1955 Toronto, Ontario, Canada
1956 Copenhagen, Denmark (electromagnetic theory and antennas)
1957 Delft, The Netherlands
1958 Stresa, Italy
1959 Tbilisi, USSR
1960 London, England
1961 Stanford, California
1962 Munich, Germany (*Radio Science*, 16(6), 1981)
1963 Santiago de Compostella, Spain (*Radio Science*, 19(5), 1984)
1964 Budapest, Hungary (*Radio Science*, 22(6) 1987)
1965 Stockholm, Sweden (*Radio Science*, 26(1-2) 1991)
1966 Sydney, Australia (*Radio Science*, 28(5-6) 1993)
1967 St. Petersburg, Russia (*Radio Science*, 31(6) 1996)
1968 Thessaloniki, Greece (*Radio Science*, 35(2) 2000)
1969 Victoria, Canada (*Radio Science*, 38(2) 2003)
2004 Pisa, Italy (*Radio Science*, 40(6) 2005)

Business meeting at the 2004 EMTS.

Attendance : Prof. Makoto Ando, Commission B, Chair, Prof. Lotfollah Shafai, Commission B, Vice-Chair, About 50 members of Commission B

Schedule:
Business meeting I: 18:00-19:00, 24 May 2004
Business meeting II: 18:00-19:00, 26 May 2004
Closing ceremony: 18:20-18:45, 27 May 2004

The Commission B Chair, Makoto Ando opens the meeting at 18:00 p.m. on Monday 24 May 2004 and welcomes all members who are interested in and supporting Commission B activities.

Request for Proposals of Venue for the 2010 EMTS

The procedure of request for proposal of Venue 2010 EMTS was announced which had been suggested by the e-mail to national representatives. A formal request for proposals concerning the venue for the 2010 EMTS will be sent out during the fall of 2004. The recently established Comm. B procedure for handling the choice of the venue will be followed. Thus, a small group (2-3 people) will be formed to go through the proposals and then to select two of them which will then be voted upon by the Comm. B representatives. The winner will be determined by a simple majority of the votes received. The request for venue proposals will contain a list of aspects that the proposers should address. The vote is expected to take place in late 2004 or early 2005 (Commission B Business meeting in 2005 GA, at the latest).

Proposals and vote for new Comm. B vice-chair for 2005- 2008

The procedure for Proposals and vote for new Comm. B vice-chair for 2005-2008 was explained by Makoto Ando. At the next URSI GA in New Delhi, India, October 2005, Comm. B will make the final vote concerning the new vice-chair for 2005-2008. The URSI requirements are that all Comm. B representatives shall have an opportunity to nominate candidates and that Comm. B shall present (at least) two names and the order of preference between them. Each Comm. B representative has one vote.

Comm. B takes a two-step procedure. In the first round all the nominated candidates participate and each Comm. B representative votes for two candidates. Each representative's first choice will receive 2 points and their second choice will receive 1 point. The two (or possibly three) candidates who get the largest number of points will advance to the second round of voting. In the second round, the representatives similarly give two points to their first choice and 1 point to their second choice.

Comm. B wants to encourage that a sufficient number of candidates are nominated and, therefore, the meeting recommended that a Comm. B Search Committee (CBSC) consisting of three Comm. B last chairs should be formed with the task of making sure that enough candidates are nominated. Past chairs Chalmers Butler and Staffan Strom will be invited to form CBSC with the current chair Makoto Ando.

The request for nominations will be sent out during the fall of 2004 and the second round of voting should take place early in 2005. Formally the votes are counted at the GA and the Comm. B representatives then have a possibility to change their votes concerning the second round at the GA if they wish to do so.

Preparations for the 2007 EMTS in Alexandria, Egypt

Said .E. El-Khami, chair of the Local Organising Committee reported the progress of the preparations for the 2007 EMTS in Alexandria, Egypt. He also mentioned that Comm. B scientists of Egyptian origin who now work abroad could form an international advisory group with the goal of providing the LOC in Alexandria with support concerning different aspects of the symposium preparations. Several suggestions for local organization of the symposium were provided from the floor based upon the experiences in Pisa.

Comments on PISA EMT-S and the future of the EMTS

Several new attempts were introduced in Pisa. / Technical Program (One-time 3-page submission, Plenary sessions, 6 room parallel, Posters with short presentation, Time tables, CD publication) / Lunch-every day / Local organization (Concert in domo) etc. Comments about the Pisa EMT-Symposium as well as future symposia were requested and discussed freely.

- A large number of submissions (>450) and registrations (400) were announced. Low no-show rate are emphasized.(20 Oral, 10 Poster -final)
- Number of parallel rooms may be too many for EMT-Symp., some suggestions to mitigate this problem were (1) to limit the presentations per registration to less than 2 or 3, (2) to reduce the time for the oral presentation (in two categories; 10minutes + 20 minutes), (3) to increase the symposium period.
- Hard-copy digest, CD and Final program
- The hard-copy digest may be replaced completely by CDs in the near future. Instead, abstracts in a few lines for each paper in the Final program would be useful and informative.
- Lunch every day in the venue included in the registration turned out to be very effective both in enhancing communications between attendees and punctual operation of technical program.
- Registration fee: in addition to the current two categories of "Regular" and "Student", a new one "Retired" may be prepared. This received substantial support from the floor.
- Commission B appreciates the B-TAB members' hard work. B-TAB supported the Pisa TPC and worked very well and is requested to continue long-term planning for EMT-S and GA as well.
- Venue selection: assessing the registration fee more than 5 or 6 years before the events may be too early due to the rapid changing of the political situation and the harmonization with the location of General assembly which is finalized only three years before. This should be studied by the Commission Chair and Vice-chair.

Preparations for the 2005 GA in New Delhi

Makoto Ando reported the latest results of the discussions in the Coordinating Committee meeting in Gent on 14-16 May. It included the "GA Preliminary Schedule" and "Scientific Session Timetable ". In the 2002 GA, text only abstracts were submitted for review and the final version of the manuscript with a maximum of 4 pages plus a 100 word abstract was requested for each accepted paper. In the 2005 GA, 4-page manuscripts are submitted once for both review and the proceedings.*(This was not adopted in 2005 GA.Only the abstracts are used for the review and full papers are requested after acception.)*

Commission B will have 11 oral sessions (10 papers x 5 + 7 papers x 5 + 4 papers x 1 =89 oral presentations) and 1 tutorial session(60 minutes = 2 x 30 minutes or 1 x 60minutes). For general lectures, three lectures were selected. "Metamaterials and plasmonic structures" was in the fourth position and finally it is included in the Program.

The status of topics were reported by Lot Shafai, Commission B Vice Chair.

Commission B sessions for GA 2005 (as on 25/06/2004)

Commission B related Oral Sessions

5 x 10 papers (L), 5 x 7 papers (M), 1 x 4 papers (S)

24/10/2005 - AM

B[01] Electromagnetic theory (I, C, P / 10) Poster 25 PM
DB[2] CAD techniques for accelerated design of electronic and electromagnetic structures
EB EM modeling for EMC

24/10/2005 - PM

B-Tutorial: Advances in Computational Models for the Design of Planar and Compact Antennas
B[08] Educational issues in Electromagnetic Theory and Applications (I / 4) Poster-25PM

25/10/2005 - AM

BCD Metamaterials, plasmonic structures and their applications (I, C, P / 10) Poster-25PM

25/10/2005 - PM

B[07] Guided waves, radiation and interference in open structures (I,C, P / 7) Poster-25PM
JB[1] Progress in mm/sub-mm telescopes and receivers
HX[1] Solar Power Satellite

26/10/2005 - AM

B[03] Inverse scattering and imaging (I, C, P / 10) Poster

26/10/2005 - PM

U2 GENERAL LECTURE 2 - Metamaterials and Plasmonic Phenomena
BCF Propagation models, MAXWELLIAN approach to smart antennas (I,C, P / 7) Poster-25PM
JB[2] Mm/sub-mm techniques and science (I, C, P)

27/10/2005 - AM

B[02] Scattering and diffraction (I, C, P / 10) Poster-27PM

27/10/2005 - PM

B[05] Numerical, asymptotic and hybrid methods (I,C,P / 7) Poster-27PM
KB Modeling of biological systems

28/10/2005 - AM

B[04] Antennas and arrays (I,C, P / 10) Poster-27PM
CBA Measurement of wireless channels (I, C / 7-10 / L or M)

28/10/2005 - PM

BC Antennas for wireless systems and mobile 1(I,C,P / 7) Poster-27PM

29/10/2005 - AM

B[06] Transient fields and ultra wide band radio systems (I, C, P / 7) Poster-27PM
CB Antennas for wireless systems and mobile 2 (I,C,P / 7)
DB[1] Near-field characterization for optics and microwaves

Commission B Poster Sessions: Prof.Ahmed Kishk

- General
- Non linear inverse scattering
- Ground penetrating radars: EM modeling, antennas, imaging and inversion
- Artificial and complex materials and surfaces for antenna
- RF aspects of smart antenna and MIMO antenna systems
- (Joint B&K) Interaction of EM waves with biological tissues
- (Joint BF) Random media and rough surfaces
- Multiphysics evaluation of RF systems and components (combined thermal, RF and mechanical modeling)

General Lecture

1. Solar power satellite
2. Metamaterials and Plasmonic Phenomena
3. Impacts of Extreme Solar Disturbances on the Earth's Near-Space Environment

Letters to the Commission B representatives

During the triennium the Chair has communicated with the Commission B official members through a series of e-mail messages.

Sponsorship for conferences within the Commission B area

Consistent with the practice of past years, Commission B has sponsored meetings held by other organisations on topics which fall within the purview of the terms of reference for Commission B. However, consistent with the policy established some years ago, Commission B only gives Mode A support (as mentioned earlier, Commission B spends its grant on Young Scientist Awards). Some 20 conferences, listed below (in Table 1) have received Mode A sponsorship.

Conclusion

It is my great pleasure to thank all those colleagues who have participated in the activities of Commission B and who have given so generously of their time and expertise. Without your contributions there would hardly be a Commission B. I would also like to express my great appreciation of the help that the URSI Secretariat and particularly Inge Heleu has always provided. That has facilitated my task enormously. Thank you all !

details meeting
Getting the Most out of the Radio Spectrum, London, U.K., 24-25 October 2002
JINA 2002, Nice, France, 12-14 November 2002
2003 IEEE Int. Symp. On Electromagnetic Compatibility, Istanbul, Turkey, 11-16 May 2003
ISMOT 2003 - 9th Int. Symp. On Microwave and Optical Technology, Ostrava, Czech Republic, 11-15 August 2003
ICEAA03, Torino, Italy, 8-12 September 2003
11th MICROCOLL, Budapest, Hungary, 10-11 September 2003
Telecom 2003 & JFMMA, Marrakech, Morocco, 15-17 October 2003
APMC 2003, Seoul, Korea, 4-7 November 2003
WARS04 (Workshop on Applications of Radio Science) conference 2004, Hobart, Tasmania, Australia, 18-20 February 2004
2004 Int. Symp. On Electromagnetic Theory (Commission B Open Symposium), Pisa, Italy, 23-27 May 2004
MSMW'04, Fifth Int. Kharkov Symposium on Physics and Eng of Microwaves, Mm and Busmm Waves, Kharkov, Ukraine, 21-26 June 2004
ISAP'04, 2004 Int. Symp. on Antennas and Propagation, Sendai, Japan, 17-21 August 2004
Bianisotropics '04, Gent, Belgium, 22-24 September 2004
JINA-04, Nice, France, 8-10 November 2004
ISAP05, Int. Symp. On Antennas and Propagation, Seoul, Korea, 3-5 August 2005
4th European Workshop on Conformal Antennas, 23-24 May 2005, Stockholm, Sweden
ISMOT 2005 - 10th International Symposium on Microwave and Optical Technology, Fukuoka, Japan, 22-25 August 2005
ICEAA'05, International Conference on Electromagnetics in Advanced Applications, Torino, Italy, 12-16 September 2005
ANTEM 2005, Antenna Technology and Applied Electromagnetics, Saint Malo, France, 15-17 June 2005

Table 1: Meetings supported by Commission B (Mode A - moral support)

COMMISSION C

This triennium report was prepared by Professor. M. Akaike, Commission C Chair 2002-2005.

1. New Terms of Reference "Radio Communication Systems and Signal Processing"

We discussed about the responsibility of Commission C in the General Assembly in Maastricht. We understand that we are now experiencing a rapidly moving Radio Science environment. Our technology is now expanding even to the outer side of the classical sense of Radio Science, that is, the mobile radio communications, ultra-wideband systems (UWB), and multiple-input multiple-output systems (MIMO) based upon signal processing and internet are playing a more and more important role in the field of Radio Science and URSI.

Surround by such a varying environment, we know that we, while actively questing a new frontier, should still always be aware of the dual aspects, i.e., the universality and the modern trend. Considering these situations, we have reached a new conclusion. The scientific sessions convened for this General Assembly in New Delhi well reflect the modern radio trend and our discussions to date.

2. 2004 International Symposium on Signals, Systems and Electronics (2004 ISSSE)

The ISSSE is an international symposium held once in every three years, one year prior to the URSI General Assembly, organized and sponsored by URSI Commissions C and D. Historically, Commission C represented signal, system-, and software-oriented technology, while Commission D represented device- and hardware-oriented technology. In recent years, however, the importance of cooperation between systems and devices, and in other words, software and hardware, has been more and more strongly recognized. In modern radio equipment, even a tiny single device can have a complex system function, and on the other hand, software gradually takes over the role of hardware. The cooperation of Commissions C and D, therefore, is quite timely and meaningful. We believe that he international and interdisciplinary characteristics of ISSSE will surely make a desirable paradigm of the present and future URSI activities.

The sixth International Symposium on Signals, Systems and Electronics was held on August 10-13 in 2004 in Johannes Kepler University Linz, Linz, Austria. Linz, a beautiful city covered with rich green, is the capital of Upper Austria, located right in-between Vienna and Salzburg. The conference was co-chaired by two Chairs, Professor Dr. Kurt Schlacher, University of Linz, Austria, and Professor Dr. Robert Weigel, University of Erlangen-Nuremberg, Germany, from Commissions C and D.

The special feature of this time is that the symposium was cosponsored or technically cosponsored by the IEEE Microwave Theory and Techniques Society (MTT-S), the IEEE COM/MTT Joint Chapter Austria, the Austrian Electrotechnical Association (ÖVE), the German Association for Electrical, Electronic & Information Technologies (VDE), the government of Upper Austria, the city of Linz, the Linz Center of Mechatronics (LCM), the University of Applied Sciences of Upper Austria, and the University of Linz.

After a workshop on smart antennas and MIMO held on August 10, the symposium was inaugurated in the morning, August 11, by a plenary keynote address, "Cross Layer Design – A Equivalence Class Approach," by Michel T. Ivrlack and Josef A. Nossek, Institute for Circuit Theory and Signal Processing, Munich University of Technology. Among nearly 130 papers submitted, 89 papers were selected for oral sessions and poster sessions. The authors came from more than 20 countries in the world, about 60 % from European countries, 30 % from Asia, and 10 % North America.

As another special feature, two papers of Commissions C and D were selected and awarded the Best Paper Award:

. Enhanced Detection Through Signal Space Diversity for a Coded MC-CDMA System" (Commission C), Ronald Raulefs, German Aerospace Center in Oberpfaffenhofen, Germany, and

. An Alexander Half-Rate Phase Detector for 80 Gb/s" (Commission D), by Jan-Louis Sundermeyer, Fraunhofer Institute for Integrated Circuits IIS in Erlangen, Germany.

The welcome social event and the subsequent banquet, another excitement for symposium attendees, were held in the monastery of St. Florian, where the folks enjoyed their cultural exchange through the evening with some unforgettable memories.

The next ISSSE will be held in Montreal, Canada, in 2007.

3. Reports from National Committees

The activity reports from some National Committees have been sent to Commission Chair.

3.1 Activities of URSI-Commission C/ France section in 2002-2004

The section has organized the following events:

1) Third international conference on « Turbo-codes », 01-05 September 2003, Brest, France
2) One day seminar on « Ultra Wide Band-UWB », 18 June 2003, Paris

For the General Assembly of URSI, in October 2005, two sessions have been proposed :

- C05 : « Advances in signal processing towards fully reconfigurable radio systems »
- CJ : « Radio ressource management and spectrum efficiency »(Maurice Bellanger, CNAM, bellang@cnam.fr)

3.2 Activities of URSI-Commission C/ Japan section in 2002-2004

URSI Commission C the nineteenth Japan Branch started with its empowered administrative committee. The committee consists of Chair, Dr. Takashi Ohira, and his seven executives elected from universities and industries in Japan. They are Dr. Makoto Taromaru (ATR), Dr. Toru Maniwa (Fujitsu), Prof. Yukihiro Kamiya (Tokyo Agri-Tech Univ), Prof. Atsushi Sanada (Yamaguchi Univ.), Dr. Kenji Itoh (Mitsubishi Electric), Dr. Noriharu Suematsu (Mitsubishi Electric), and Prof. Hiroyoshi Yamada (Niigata Univ.).

The committee is also advised by its distinguished cardinals: Prof. Masami Akaike (Science Univ. of Tokyo) and Prof. Kohji Mizuno (Tohoku Univ.). The Japan Branch holds an AdCom meeting every month to discuss and plan the future activities and events related to Commission C. The Japan Branch also holds technical meetings four times a year, which are open to public, and therefore, everyone can take part with. The meetings offer three or four invited speakers presenting the state-of-the-art science and technologies on radio systems and signals. The meetings cover the technical areas including radio communication systems, cellular base stations, mobile handsets, signal processing, microwave circuits, adaptive array antennas, and high-frequency materials.

The typical topics of the meetings are as follows:

(1) “Towards Future Radio Systems”, January 30, 2004,
(2) “Attempts to discover new electro-magnetic technology by studying the past through scrutiny of the old”, May 28, 2004,
(3) “Radio Waves from the Northern Country”, July 20, 2004,
(4) “Radio Waves and Challenge to the Shannon Limit”, October 22, 2004,
(5)”Radio Waves for Space Science and Systems”, January 28, 2005,
(6) “Radio Waves and Biology”, July 20, 2005

Based upon the presentations/posing-problems made by invited key speakers, a thorough discussion was made by several tens of participants.

In addition to these events, Japan Branch cooperatively sponsors Asia-Pacific Microwave Conference 2005 held in Yokohama, and Korea-Japan Microwave Conference 2005 held in Busan, Korea. (Takashi Ohira, ATR, ohira@atr.jp)

3.3 Activities of URSI-Commission C/ Poland section in 2002-2004

The section has co-organized the following events:

1. International Conference on Signals and Electronic Systems (ICSES’2002), Wroclaw-Swieradow Zdroj, Poland, 24-27 September 2002.
   The Conference was organized by Institute of Telecommunication and Acoustics, Wroclaw University of Technology in co-operation with Signals, Network and Electronic Systems Section of Electronics and Telecommunication Committee of Polish Academy of Sciences, Circuits and Systems Chapter of IEEE Polish Section and URSI Commission C of Poland.
2. International Conference on Signals and Electronic Systems (ICSES’2004),Poznan, Poland, 13-15 September 2004.
   The Conference was organized by Institute of Electronics and Telecommunications, Poznan University of Technology in co-operation with IEEE Circuits and Systems Society, Signals, Network and Electronic Systems Section of Electronics and Telecommunication Committee of Polish Academy of Sciences and URSI Commission C of Poland.
3. 11th International Workshop on Systems, Signals and Image Processing (IWSSIP’04), Poznan, Poland, 13-15 September 2004.
   The Conference was organized by Institute of Electronics and Telecommunications,
   Poznan University of Technology in co-operation with IEEE Circuits and Systems Society, Signals, Network and Electronic Systems Section of Electronics and Telecommunication Committee of Polish Academy of Sciences and URSI Commission C of Poland.
4. XI National Symposium of Radio Science (URSI 2005), Poznan, Poland, 7-8 April 2005.
   The Conference was organized by Institute of Electronics and Telecommunications, Poznan University of Technology in co-operation with National Committee of URSI and Polish Academy of Sciences.
   (Marian S. Piekarski, Institute of Telecommunication and Acoustics, Wroclaw University of Technology)

Reports from other National Committees will be added in the website.

4. Conferences Supported by Commission C

The following conferences were supported by Commission C.

1) **APMC’02** : Asia-Pacific Microwave Conference, Kyoto, Japan, 19-22 November 2002
2) The 11th **MICROCOL**, Budapest, Hungary, 10-11 September 2003
3) **Workshop on Applications of Radio Science 2004(WARS04)**, Hobart, Tasmania, Australia, February 18-20, 2004
4) **Euro Electromagnetics 2004 (EUROEM 2004)**, Magdeburg, Germany, July 12-16, 2004
5) **ISSSE 2004**, International Symposium on Signals, Systems and Electronics, Linz, Austria, 10-13 August 2004
6) **AP-RASC 04** - The 2nd Asia-Pacific Science Conference, Beijing, China, August 20-23, 2004.
7) **Radar 2004**, Toulouse, France, 19 - 21 October 2004
8) **First International Workshop on Wireless Communications in Underground and Confined Areas**, Val d’Or, Quebec, Canada, 6-7 June 2005
9) **International Symposium on Antenna and Propagation (ISAP 2005)**, Seoul, Korea, August 3-5, 2005.
10 **Microwaves, Radar and Remote Sensing**, Kiev, Ukraine, September 19-21, 2005.

Next triennium :

11) **EUSAR 2006**, Dresden, Germany, 16-18 May 2006
12) **Asia-Pacific Microwave Conference (APMC 2006)**, Yokohama, Japan, December 12-25, 2006

COMMISSION D

This triennium report was prepared by Professor P. Russer, Commission D Chair 2002-2005.

The growing importance of wireless and optical communication technology coupled with the internet growth has led to continued strong interest in the activities of Commission D, "Electronics and Photonics".

Since electronic and photonic devices have reached system level, the commission noted that this development has to be considered in the terms of reference. At the 2002 General Assembly it was resolved unanimously to change the terms of reference in the following way:

The first term of reference "Electronic devices and applications" has been changed to "Electronic devices, circuits and applications" and the second term of reference "Photonic devices and applications" has ben changed to "Photonic devices, systems and applications".

Commission D has continued the successful policy of providing technical co-sponsorship to a number of meetings of interest to Commission D while focusing financial sponsorship on the established International Symposium on Signals Systems and Electronics, ISSSE, jointly sponsored with Commission C. For this triennium we also provided financial sponsorship to the 2004 Asia-Pacific Radio Science Conference (AP-RASC'04).

1. 2004 International Symposium on Signals, Systems and Electronics (ISSSE'04) in Linz, Austria

The 6th International Symposium on Signals, Systems, and Electronics, ISSSE 2004, was held in Linz, Austria on August 10-13, 2004. ISSSE is an international symposium held once every three years. This symposium is organized and sponsored by the International Union of Radio Science (URSI), Commissions C and D. ISSSE 2004 was technically co-sponsored by the IEEE Microwave Theory and Techniques Society (MTT-S), the IEEE COM/MTT Joint Chapter Austria, the Austrian Electrotechnical Association (ÖVE), the German Association for Electrical, Electronic & Information Technologies (VDE), and co-sponsored by the government of Upper Austria, the city of Linz, the Linz Center of Mechatronics (LCM), the University of Applied Sciences of Upper Austria, and the University of Linz. General Chairmen were Kurt Schlacher of the University of Linz, Austria, and Robert Weigel of the University of Erlangen-Nuremberg, Germany. Technical Program Chairmen were Andreas Springer of the University of Linz, Austria, and Gernot Kubin of the University of Graz, Austria. ISSSE 2004 provided a full 3-day program, which was composed of two keynote speeches, a large number of regular sessions, poster sessions, and a tutorial on smart antennas and MIMO. The symposium proved to be an inspiring forum for discussions, exchange of ideas, and the possibility to maintain and initiate fruitful networks between scientists and developers in the fields of signal- and system theory, electronic components, and communications engineering. After the review of nearly 130 submissions, 89 were accepted for presentation. Authors came from more than 20 countries, thereof 63% from Europe, 29% from Asia, and 8% from North America. During the symposium two best papers have been awarded. The winner of the ISSSE'04 URSI commission C Best Paper Award is Ronald Raulefs from the German Aerospace Center in Oberpfaffenhofen, Germany, for his paper entitled "Enhanced Detection Through Signal Space Diversity for a Coded MC-CDMA System", while Jan-Louis Sundermeyer from the Fraunhofer Institute for Integrated Circuits IIS in Erlangen, Germany, received the ISSSE'04 URSI commission D Best Paper Award for his paper "An Alexander Half-Rate Phase Detector for 80 Gb/s". For further information concerning ISSSE 2004 please refer to http://www.icie.jku.at/issse04/. The next ISSSE will presumably be held in Montreal, Canada in 2007.

2. Conferences Supported by Commission D

The following conferences were supported by Commission D:

1. **MMET'02**, Int. Conf. on Mathematical Methods in Electromagnetic Theory, Kiev, Ukraine, 10-13 September 2002,
2. **Getting the Most out of the Radio Spectrum**, London, U.K., 24-25 October 2002,
3. **ISMOT 2003** - 9th Int. Symp. On Microwave and Optical Technology, Ostrava, Czech Republic, 11-15 August 2003,
4. **11th MICROCOL**L, Budapest, Hungary, 10-11 September 2003,
5. **CAOL 2003**, Int. Conference on Advanced Optoelectronic and Lasers, Alushta, Crimea, Ukraine, 16-20 September 2003,
6. **Telecom 2003 & JFMMA**, Marrakech, Morocco, 15-17 October 2003,
7. **MSMW'04**, Fifth Int. Kharkov Symposium on Physics and Eng of Microwaves, Millimeter- and Submillimeter-Waves, Kharkov, Ukraine, 21-26 June 2004,
8. **ISSSE'04**, International Symposium on Signals, Systems and Electronics, Linz, Austria, 10-13 August 2004
9. **AP-RASC 04**: 2004 Asia-Pacific Radio Science Conference, Beijing, China, 20-23 August 2004,
10. **ISMOT 2005** - 10th International Symposium on Microwave and Optical Technology, Fukuoka, Japan, 22-25 August 2005,
11. **CAOL 2005**, Int. Conference on Advanced Optpelectronic and Lasers, Yalta, Crimea, Ukraine, 12-17 September 2005,

It already has been decided that the he following conference will be supported by Commission D in the next triennium from 2005 to 2008:

12. **AP-RASC 07**: 2007 Asia-Pacific Radio Science Conference, Perth, Australia,

3. The 2005 General Assembly

The technical areas of interest to Commission D have been well-supported for the Delhi General Assembly, with 89 oral papers and 6 poster papers. We are pleased that Prof. Dr. Paolo Lugli, (Munich University of Technology, Munich, Germany) gives the Commission D Tutorial on the subject of "**Nanoelectronics**". The papers are scheduled in the following sessions:

- **D01 - Millimeter Wave Wireless Systems,** Roberto Sorrentino (Italy), Ching-Kuang C. Tzuang (China SRS),
- **D02 - Hardware Aspects of Metamaterial Structures (I,C,P),** Convener: Tatsuo Itoh (USA), Co-convener: Christophe Caloz (Canada),
- **D03 - Si and SiGe RF integrated Circuits for Communications and Sensorics,** Convener: Robert Weigel (Germany),
- **D04 - Organic devices for radioscience applications,** Convener: Aldo Di Carlo (Italy)
- **D05 - Nanoelectronic devices (I,C,P),** Paolo Lugli (Germany),
- **D06 - Device and circuit modelling**, Convener: Samir El-Ghazaly (USA),
- **D07 - Optical devices (I,C,P),** Convener: Franz Kaertner (USA),
- **D08 - Frontend modules and integrated antennas (I,C,P),** Convener: Stefan Lindenmeier (Germany),
- **DB1 - Near-field Characterization for optics and microwaves (I,C,P),** Convener: Frédérique de Fornel (D, France), Co-convener: Kazuo Tanaka (B, Japan),
- **DB2 - CAD techniques for accelerated design of electronic and electromagnetic structures,** Convener: Natalia K. Nikolova (D, Canada), Co-convener: Roberto Sorrentino (B, Italy),
- **DP - Contributed Poster Session,** Convener: Maurice Pyée (France),
- **DT - TUTORIAL D – Nanoelectronics,** Convener: P. Russer (Commission Chair), Co-convener: F. de Fornel (Commission Vice-chair), Lecturer: Paolo Lugli (Germany),

COMMISSION E

This triennium report was prepared by Professor P. Degauque, Commission E Chair 2002-2005.

During the Maastricht URSI General Assembly, it was decided to slightly change the various working groups (WG) in order to renew and update their field of interest. During this triennium, the *Working Groups* were:

E.1:Terrestrial and Planetary Electromagnetic Noise Environment
Co-Chairs: M. Hayakawa (Japan), A.P. Nickolaenko (Ukraine), Y. Hobara (France) and M. Füllekrug (Germany)

E.2:Intentional Electromagnetic Interference
Co-Chairs: M. Bäckström (Sweden) and W. Radasky (USA)

E.3:High Power Electromagnetics
Co-chairs: C.E. Baum (USA) and R.L. Gardner (USA)

E.4:Lightning Discharges and Related Phenomena
Co-chairs: Z. Kawasaki (Japan)

E.5:Interaction with and Protection of, Complex Electronic Systems
Co-chairs: J. Nitsch (Germany), P. Degauque (France) and J.P. Parmentier (France)

E.6:Extra-Terrestrial and Terrestrial Meteorologic-Electric Environment
Chair: H. Kikuchi (Japan), E.A. Mareev (Russia)

E.7:Geo-electromagnetic Disturbances and Their Effects on Technological Systems
Chair: A. Viljanen (Finland)

E.8: Interference and Noise at Frequencies above 30 MHz
Chair: J. Gavan (Israel)

Joint Working Group

EGH. Seismo Electromagnetics (Lithosphere-Atmosphere-Ionosphere Coupling)
Co-Chair for Commission E: M. Hayakawa (Japan)
Co-Chair for Commission G: S. Pulinet (Russia)
Co-Chair for Commission H: M. Parrot (France) and O.A. Molchanov (Russia)

During the EMC Zurich meeting in 2000, a discussion took place on the role of these WGs and on a possible change of their role and on the way of conducting their activities. It appears that a majority of attendants was in favor of keeping a light structure and of leaving to the WG co-chairs the responsibility of developing the cooperation within their WG as they want to do.

Most of the Commission E activities have thus been devoted to the organization of meetings and conferences and to the preparation of the New Delhi General assembly.

In Europe, a debate and discussions between the organizers of the main EMC European events took place during the triennium about the idea of merging or not few meetings. For the time being, there is no strong consensus and the number of national or European meetings remains as it was.

Furthermore it must be outlined that, within the EMC conferences, an increasing number of sessions were devoted to applications in different domains as: automotive, railway system, power engineering, etc. and to EMC in wire and wireless communication system.

Commission E has sponsored the following meetings These meetings cover nearly all aspects of EMC and its applications.

Meetings	mode
EMF and Cardiac Pacemakers and Defibrillators, Paris, France, 25 October 2002	A
EMC Zurich 2003, Zurich, Switzerland, 18-20 February 2003	B
2003 IEEE Int. Symp. On Electromagnetic Compatibility, Istanbul, Turkey, 11-16 May 2003	B
Telecom 2003 & JFMMA, Marrakech, Morocco, 15-17 October 2003	A
WARS04 (Workshop on Applications of Radio Science) conference 2004, Hobart, Tasmania, Australia, 18-	A
EMC'04 Sendai - 2004 International Symposium on Electromagnetic Compatibilty, Sendai, Japan, 1-4 June	A
EMC Wroclaw 2004, Wroclaw, Poland, 29 June - 1 July 2004	B
AP-RASC 04: 2004 Asia-Pacific Radio Science Conference, Beijing, China, 20-23 August 2004	A
Radar 2004, Toulouse, France, 19 - 21 October 2004	A
EMC Zurich 2005, Zurich, Switzerland, 15-17 February 2005	B
Telecom 2005 & JFMMA, Rabat Morocco, 23-25 March 2005	A
VIth International Symposium on Electromagnetic Compatibility and Electromagnetic Ecology, St.	B
ICEAA'05, International Conference on Electromagnetics in Advanced Applications, Torino, Italy, 12-16	A
Microwave, Radar and Remote Sensing, Kiev, Ukraine, 19-21 September 2005	A

COMMISSION F

This triennium report was prepared by Prof. Martti Hallikainen, Commission F Chair 2002-2005.

Introduction

The officers of Commission F during the triennium 2002-2005 have been Prof. Martti Hallikainen (Finland), Chair, and Prof. Piotr Sobieski (Belgium), Vice Chair. Immediate Past Chair has been Dr. Yoji Furuhama (Japan). Commission F has been active during the triennium through its Working Groups, by sponsoring meetings and symposia, and by preparing the scientific program for the General Assembly 2005.

Terms of Reference

The following Terms of Reference of Commission F were accepted at the General Assembly 2002: "Commission F – Wave Propagation and Remote Sensing (planetary atmospheres, surfaces and subsurfaces)

The Commission encourages:

(a) The study at all frequencies in a non-ionised environment:
 (i) wave propagation through planetary neutral atmospheres and surfaces,
 (ii) wave interaction with planetary surfaces and subsurfaces including land, ocean and ice,
 (iii) characterization of the environment as it affects wave phenomena;
(b) The application of the results of these studies, particularly in the areas of remote sensing and communications;
(c) The appropriate co-operation with other URSI Commissions and other relevant organizations."

Reports from Working Groups and Representatives to Other Organisations

FG Ionosphere and Atmosphere Remote Sensing Using Satellite Navigation Systems

Co-Chair for Commission F: B. Arbesser-Rastburg (The Netherlands)
Co-Chair for Commission G: C. Mitchell (UK)

The joint Working Group organized a special symposium "Atmospheric Remote Sensing Using Satellite Navigation Systems", held from 13-15 October 2003 in Matera, Italy (see Commission F sponsored Mode B meetings).

GF Middle Atmosphere

Co-Chair for Commission G: J. Röttger (Germany)
Co-Chair for Commission F: C.H. Liu (China SRS)

HCDFG Solar Power Satellite (SPS)

Co-Chair for Commission F: S. Reising (USA)

The URSI Inter-commission Working Group (ICWG) on Solar Power Satellites (SPS) is in the process of composing an URSI White Paper on Solar Power Satellites (SPS). This white paper is based on inputs from representatives of all URSI Commissions. Commission F input is on the subject of Solar Power Satellites, particularly with respect to concerns of radio frequency interference to remote sensing systems.

SCOR (Scientific Committee on Oceanic Research)
Commission F representative: P. Sobieski (Belgium)

IUCAF (Inter-Union Committee on Frequency Allocations for Radioastronomy and Space Research)
Commission F representative: A. Gasiewski (USA)

SCT (Scientific Committee on Telecommunications)

Commission F representative: J. Isnard (France)

In order to be informed about ITU-R events J. Isnard participated in all SG7 (Study Group 7) sessions (Scientific Services) of ITU-R with the financial support of the French National Committee of URSI. After each session a report was sent to members of SCT Network on current issues discussed and on technical subjects that could be of interest to URSI members. This activity mainly covers the "remote sensing" aspect of F Commission. Moreover, J. Isnard kept in touch with URSI members who participate regularly in SG3 "Propagation" of ITU-R as members of the French ANFR (Frequency Radio Agency) delegation to this ITU-R Study Group.

Commission F Editor for The Radio Science Bulletin

Commission F Editor for RSB.: P. Sobieski (Belgium)

The following two review articles were collected by M. Hallikainen and published in the Radio Science Bulletin:
- P. Pampaloni and K. Sarabandi: Microwave Remote Sensing of Land (RSB, March 2004, pp. 30-48)
- E. Westwater, S. Crewell, and Ch. Mätzler: A Review of Surface-based Microwave and Millimeterwave Radiometric Remote Sensing of the Troposphere (RSB, September 2004, pp. 59-80).

Commission F Sponsored Meetings

Commission F sponsored 26 Mode A meetings (no financial support requested) and 6 Mode B meetings (financial support requested). All sponsored meetings are listed below. If the web site is still accessible its address is given.

Mode A Sponsorship

- **MMET 2002**: International Conference on Mathematical Methods in Electromagnetic Theory, Kiev, Ukraine, 10-13 September 2002.
- **The 34th COSPAR Scientific Assembly**: Held in Houston, Texas, USA, 10-19 October 2002 (http://134.76.248.97/COSPAR/COSPAR_houston.html).
- **Getting the Most out of the Radio Spectrum**: Held in London, United Kingdom, 24-25 October 2002.
- **APMC 2002**
  2002 Asia-Pacific Microwave Conference, Kyoto, Japan, 19-22 November 2002.
- **ISAR-3**: Third International School on Atmosphere Radar, ICTP Trieste, Italy, 25 November – 13 December 2002.
- **ISAP-i02**: Intermediate International Symposium on Antennas and Propagation, Yokohama, Japan, 26-28 November 2002.
- **MST-10**: Tenth International Workshop on Technical and Scientific Aspects of MST Radar, Piura, Peru, 20-27 May 2003.
- **IEEE EMC 2003**: 2003 IEEE International Symposium on Electromagnetic Compatibility (EMC), Istanbul, Turkey, 11-16 May 2003 (http://www.ortra.com/emc2003).
- **IGARSS'03**: 2003 IEEE International Symposium on Geoscience and Remote Sensing, Toulouse, France, 21-25 July 2003.
- **ISMOT 2003**: Ninth International Symposium on Microwave and Optical Technology, Ostrava, Czech Republic, 11-15 August 2003.
- **11th MICROCOLL**: Held in Budapest, Hungary, 10-11 September 2003.
- **Telecom 2003 & JFMMA**: Held in Marrakech Morocco, 15-17 September 2003.
- **APMC 2003**: 2003 Asia-Pacific Microwave Conference, Seoul, Korea, 4-7 November 2003 (http://www.apmc2003.org).
- **WARC04**: Workshop on Applications of Radio Science, Hobart, Tasmania, Australia, 18-20 February 2004.
- **MSMW'04**: Fifth International Kharkov Symposium on Physics and Engineering of Microwaves, Millimeter and Submillimeter Waves, Kharkov, Ukraine, 21-26 June 2004.
- **The 35th COSPAR Scientific Assembly**: Held in Paris, France, 18-25 July 2004 (http://134.76.248.97/COSPAR/COSPAR_paris.html).
- **ICT 2004**: ICT 2004 African Regional Workshop, Nairobi, 16-20 August 2004.
- **ISAP'04**: 2004 International Symposium on Antennas and Propagation, Sendai, Japan, 17-21 August 2004.
- **IGARSS'04**: 2004 IEEE International Symposium on Geoscience and Remote Sensing, Anchorage, Alaska, USA, 20-24 September 2004.
- **Radar 2004**: Held in Toulouse, France, 19-21 October 2004.
- **ETTC 2005**: European Test & Telemetry Conference 2005, Toulouse, France, 7-9 June 2005 (http://www.ettc2005.org).
- **IGARSS'05**: 2005 IEEE International Symposium on Geoscience and Remote Sensing, Seoul, Korea, 25-29 July 2005.
- **ISAP'05**: 2005 International Symposium on Antennas and Propagation, Seoul, Korea, 3-5 August 2005 (http://www.isap05.org).
- **ISMOT-2005**: 10th International Symposium on Microwave and Optical Technology, Fukuoka, Japan, 22-25 August 2005 (http://ismot2005.fit.ac.jp).
- **MRRS 2005**: Microwaves, Radar and Remote Sensing 2005, Kiev, Ukraine, 19-21 September 2005 (http://congress.org.ua/mrrs).
- **ClimmDiff'05**: Held in Cleveland, Ohio, USA, 26-27 September 2005 (http://spectrum.nasa.gov/climdiff).

- **URSI Joint Working Group FG Workshop**: Commission F Symposium on Microwave Remote Sensing Atmospheric Remote Sensing Using Satellite Navigation Systems, URSI Joint Working Group FG, Matera, Italy 13-15 October 2003 (Conference report: RSB, December 2003, pp. 64-65). The four themes were atmospheric/ionospheric measurements using ground-based GNSS receivers, GNSS radio occultation and novel radio occultation techniques, scintillation – ionospheric and tropospheric effect, and imaging and data assimilation techniques. The young scientist session covered each of the four themes.
- **ClimmDiff'03**: Fortaleza, Brazil, 17-19 November 2003 (Conference report: RSB, March 2004, pp. 59-62). The meeting extended the Climpara meetings linking URSI with ITU-R and addressed the use of climatic parameters in the prediction of radiowave propagation characteristics and diffraction modelling and its applications. The meeting preceded parallel meetings of ITU-R Working Parties 3J, 3K, 3L, and 3M. 60 participants attended the meeting and 35 contributed papers were presented.
- **MICRORAD 2004**: 8th Specialist Meeting on Microwave Radiometry and Remote Sensing Applications, Rome, Italy, 24-27 February 2004. Topics included satellite missions and experimental campaigns, sensor calibration, advanced techniques, retrieval methodologies, and several applications (ocean, atmosphere, snow, soil and vegetation. 152 participants attended the meeting. 85 oral and 42 interactive presentations were given.
- **Commission F Triennial Open Symposium**: Cairns, Great Barrier Reef, Australia, 1-4 June 2004 (http://www.ursi-f2004.com). Topics covered both radiowave propagation and remote sensing. 40 participants attended the meeting. 4 invited and 26 contributed papers were presented.
- **AP-RASC'04**: 2004 Asia-Pacific Radio Science Conference, Qingdao, China, 25-27 August 2004. The meeting covered all scientific fields of URSI. A total of 17 keynote speeches, 6 invited presentations and over 200 contributed presentations were given.
- **Commission F Triennial Symposium on Microwave Remote Sensing**: Commission F Symposium on Microwave Remote Sensing of the Earth, Oceans, Ice, and Atmosphere, Barza d'Ispra, Italy, 20-21 April 2005 (http://ursi-f-2005.jrc.it) (Conference report: June RSB, 2005, p. 77). Topics included SAR, SAR interferometry, early warning of earthquakes and tsunami, ground-based systems, ESA SMOS mission, monitoring of snow cover, and radar polarimetry. 62 participants attended the meeting. 40 oral and 8 interactive presentations were given.

Preparation of Scientific Programme for General Assembly 2005

Setting up a scientific program for a triennium is the prime activity of an URSI Commission in order to achieve an exchange of ideas and research results among individual scientists throughout the world. This is carried out at General Assemblies and other meetings.

Traditionally, Commission F oral sessions at GA have been organised based on invitation only. It was agreed at GA 2002 to open the oral sessions for contributed papers in order to have opportunities especially for Young Scientist Programme awardees to present their results. All Commission F sessions at GA 2005 consist of invited and contributed presentations and, additionally, related poster presentations. The following sessions are planned:

F01 - Satellite and terrestrial propagation
F02 - Propagation and scattering in vegetation
F03 - Mobile and personal access radio propagation
F04 - Mobile and indoor propagation
F05 - Scattering and diffraction effects in remote sensing
F06 - Global remote sensing
F07 - Urban remote sensing
F08 - Novel sensors and data fusion
F09 - Microwave remote sensing of the cryosphere
F10 - Remote sensing of atmosphere and ocean
FG - Transionospheric signal degradation
BCF - Propagation models and Maxwellian approach to smart antennas
GF1a, b - Atmosphere-ionosphere sounding by using global navigation satellite systems

The Commission F Tutorial is entitled "Spaceborne radar mapping of boreal forests".

Communications

The Commission F web site has been established in connection of the URSI web site (http://www.ursi.org) for efficient dissemination of information.

COMMISSION G

This triennium report was prepared by Prof. Christian Hanuise, Commission G Chair 2002-2005.

1. Introduction

During the triennium 2002-2005, URSI Commission G has been active through its Working Groups (WGs) and sponsored symposia and workshops. The Commission has a website hosted by URSI and an electronic mailing list for communicating with people who have expressed an interest in Commission G activities. The address is http://www.ips.gov.au/mailman/listinfo/ursi-commission-g. The mailing list membership is self-managing and the Commission Chair moderates the group. Currently, there are 709 addresses in the mailing list.

2. Working Groups Reports

The following Working Groups reports have been prepared by the Working Group Chairs in cooperation with their co-chairs.

2.1 G1: Ionosonde Network Advisory Group

Chair: T. Bullett (USA), Vice-Chair: C Davies (UK), INAG Editor: P. Wilkinson (Australia)

Activity within INAG has been low during the last three years, according to the relatively few numbers of articles in the INAG bulletin and messages in the INAG email list. This quiet period is likely to end soon, as many ionosouding technical developments are about to become public.

The mailing list membership has risen to 247 members. All failed addresses have been purged from this list so although the membership is quiet, at least the list is active and growing at a slow rate.

The first INAG Bulletin appeared in September 1969 and has proven a useful source of information on ionosondes and ionosonde data and short notes on ionospheric measurements and data analysis. For some years now the Bulletin has only appeared on the Web. It was decided at the last Assembly there would be a separate volume per year and consequently there were three Bulletins issued this triennium (numbers 64, 65 & 66). Collectively, this amounted to eight articles. Chris, Phil and I would like to thank the authors of these articles for taking the time to support the Bulletin.

One further project was commenced during this triennium but has not yet been completed. During the last triennium UAG-23A, the URSI ionogram scaling conventions, was converted to a PDF document and made available through the INAG Bulletin web pages. Currently, John Titheridge's report on POLAN, UAG-93, is being converted to PDF and will be placed on the INAG Website when the conversion is completed.

Over the last three years there have been many technical developments in the ionosonde community. However, most of these are still under development by their respective institutions, and are not yet ready for announcement or in need of INAG guidance. One such example is the imminent use of ionosonde derived electron density profiles by data assimilation ionosphere models. These models use multiple data types and have optimal estimation algorithms such as the Kalman filter. These applications require quantified uncertainty or error estimates in the observations. Once the techniques for making these error bars are developed and validated by the various ionosonde camps, some new data exchange format is required.

Ionosonde owners and operators still practice commendable levels of data sharing, although international fiscal and intellectual property pressures endanger this foundation, without which the ionosonde would be relegated to historical obscurity.

Vital data sharing efforts are fundamental to the various real time ionosonde data networking efforts. In addition to the venerable Digital Ionospheric Sounding System network run by the US Air Force, networks of ionosondes are being established or expanded in Europe (DIAS), Australia (IPS), South Africa, and other regions. Data exchange is evolving from a scheme where individual sensors report hourly scaled ionogram characteristics to a local world data center into a model where sensors report high time resolution ionogram data over the Internet in real time to regional data or warning centers, with data exchange occurring between the regional data centers. Relational database and web services information technologies are being applied to ionosonde networks with great effectiveness. INAG's role in this development is one of supporting standards of data interchange and advocating open and generous exchange of these data.

INAG believes it still has a useful role to play and wishes to continue as an URSI Working Group in the forthcoming triennium.

2.2 G2: Studies of the ionosphere using beacon satellites

Chair: R. Leitinger (Austria), Vice-Chairs: J.A. Klobuchar (USA; until October, 2004); P. Doherty (USA, since October, 2004) and P.V.S. Rama Rao (India)

The Beacon Satellite Group (BSG) is interdisciplinary, servicing science, research, applications, and engineering interests.

The Working Group was active in its traditional fields, namely compilation, exchange and dissemination of information, contact with and exchange of experience with various organisations of relevance (ITU-R Study Group 3, the European COST Action 271, Augmentation Systems for GPS based satellite navigation, international and national advisory bodies, GPS data retrieval and archiving organisations, and others), providing advise on request.

The work was partly carried out by correspondence, and partly through attendance of conferences and other meetings.

Among the most important activities of the BSG are the Beacon Satellite Symposia. After a forerunner organised at the Max-Planck-Institut für Aeronomie at Lindau/Harz, Germany, in 1970 the series started in 1972 with the first Symposium at Graz/Austria and continued at time intervals between two and four years. Keeping the three years rhythm the next is planned for 2007. The venue for which we have two invitations will be selected according to funding and travel / local expenses possibilities.

The **Beacon Satellite Symposium 2004** again ranks among the most successful ones. The venue was at the Abdus Salam International Center for Theoretical Physics (ICTP), Trieste, Italy from 18 through 22 October, 2004.

Scientific Committee

- Prof. Reinhart Leitinger, University of Graz, Austria (Reinhart.Leitinger@uni-graz.at)
- Prof. P.V.S. Rama Rao, Andhra University, Visakhapatnam, India (palurirao@yahoo.com)
- Ms. Patricia Doherty, Boston College, USA (Patricia.Doherty@bc.edu)
- Prof. Sandro Radicella, ICTP, Trieste, Italy (rsandro@ictp.trieste.it)
- Dr. Ed Fremouw, NorthWest Research Associates, USA (Ed@nwra.com)

Local Organizing Committee

- Prof. Sandro Radicella, ICTP, Trieste, Italy E-mail: rsandro@ictp.trieste.it
- Mr. Bruno Nava, ICTP, Trieste, Italy E-mail: bnava@ictp.trieste.it
- Dr. Biagio Forte, ICTP, Trieste, Italy E-mail: bforte@ictp.trieste.it
- Mr. Adriano Maggi, ICTP, Trieste, Italy E-mail: maggi@ictp.trieste.it

The **statistics** on the Beacon Symposium are as follows:

- Number of participants: 89
- Number of countries represented: 22
- Number of sessions: 17 (15 oral sessions and 2 poster sessions)
- Number of papers presented: 102 (counting posters)
- Number of sponsors with substantial monetary support:2

During the opening ceremony the participants were welcomed by Prof. Sandro Radicella on behalf of the host organization. The director of the Abdus Salam ICTP, Dr. Katepalli R. Sreenivasan, joined later in the week with formal welcomes and thanks for bringing a unique scientific group to ICTP. Dr. Ken Davies presented a tribute to two recently deceased members of our community, Dr. K.C. Yeh and Dr. Elizabeth Essex. Drs. Yeh and Essex were long-term members of our scientific community and their contributions have been many and important ones.

At the end of the opening ceremony Dr. Leitinger announced the recent retirement of his friend and co-chair, Mr. Jack Klobuchar and thanked him for his long-term contributions. He announced that Patricia Doherty has acted in Jack's absence and will assume the role of Western Region co-chair. This change in WG2 leadership was accepted unanimously by the Working Group.

BSS 2005 also included meetings of The International Ionospheric Tomography Community (IITC). This BSS studies sub-group was born at BSS'01 under the direction of Dr. Ed Fremouw. At IITC's 2004 meeting, tomography research results, ideas and plans for participation in the IPY 2007-2008 were discussed. The IITC Web site may be found at http://www.nwra-az.com/iitc/main.html. In addition, a new sub-group was formed to study matters of advanced GNSS-based navigation systems under the leadership of Ms. Patricia Doherty. A third interest group was formed to determine the feasibility of archiving historical ionospheric data sets. This group has collected a variety of irreplaceable data sets that should be archived for future studies.

The Beacon Satellite Group is pleased and very grateful that due to substantial financial support from ICTP it was possible to support students and participants from developing countries. The financial support from the US Federal Aviation Agency allowed us to have a very good representation from South America, India and other countries. Since ICTP provided the meeting facilities and the printed material distributed to the participants, it was possible to exempt from the registration fee all "young scientists" and all participants who got financial assistance. Coupled with inexpensive accommodation and reasonable travel costs this enabled a comparatively large number of "young scientists" to attend. The Beacon Satellite Group misses a "real" young scientist programme of URSI and urges Commission G to formulate relevant opinions.

There have already been two offers to host the next meeting in three years. More information on those plans will be announced as they mature.

From the beginning there have been two main areas of interest in Beacon Satellite Studies which can be summarised under the key words: "Electron Content" and "Scintillation". With the developments in Ionosphere Tomography and with the Global Satellite Navigation Systems (GNNS, presently the US system GPS and its Russian equivalent, GLONASS) and GPS receivers onboard Low Earth Orbit Satellites (LEOs) the "Electron Content" part gained new momentum and new perspectives. However, there is also renewed interest in scintillation studies, especially for satellite based navigation systems.

There is now considerable interest in assessment studies for various applications of satellite-to-ground and satellite-to-satellite propagation of L band signals. Very large numbers of GPS receivers are operated by different organisations, many of who lack experience with the ionosphere and plasmasphere propagation effects. The members of the BSG produce only a small fraction of data compared with the very large amount of potentially usable GPS data collected elsewhere. However, the members of the BSG have expertise in the ionosphere and plasmasphere and need to assess so-called "ionosphere products" produced by others, to provide advice, suggestions and even warnings. It is an important task for the BSG to organise assessment studies, to act as a distribution centre for relevant requests and to archive answers of more general interest.

GNSS-LEO occultation is a very important source of ionospheric data but needs further relevant assessment studies. GNSS occultation receivers will be installed simultaneously on several LEO satellites in the near future. The primary purpose is neutral atmosphere research and system development (e.g., climate research, possible data sources for weather prediction systems). These ambitious applications (e.g., to gain stratospheric temperature or tropospheric water vapour profiles) need to include very careful consideration of the residual plasma influences that necessarily remain after removal of the first order influences.

VHF/UHF beacons onboard Low Earth Orbit satellites still exist and a successor system is in sight to replace the NIMS system with three active but very weak operational beacons. Ground reception of the VHF/UHF beacon signals provides the data for high-resolution ionosphere tomography.

A considerable amount of high quality ionosphere and plasmasphere data is derived from ground and space observation of GNSS signals. However, these "Novel Data Sources" and the relevant data retrieval and preparation procedures still need careful testing and comparison with data from established instrumentation.

We continue to have a need for high resolution and high accuracy absolute values of vertical and slant electron content, especially in the context of near real-time ionospheric corrections for advanced satellite navigation systems. Other applications (e.g., the use of GNSS signals in surveying) need information on smaller scale wavelike disturbances (mostly, but not exclusively, from Travelling Ionospheric Disturbances).

The Working Group wishes to continue its activities as an URSI Commission G Working Group in the future and has endorsed its present leadership. Since traditional and new activities are well within the terms of reference of the Working Group, it does not suggest a change of these terms.

2.3 G3: Incoherent scatter

Chair: W. Swartz (USA), Vice-Chair: J.P. Thayer (USA)

Establishing "World Day" (WD) schedules to coordinate experiments at all the incoherent scatter radars and associated instrumentation is one of the activities of the URSI Incoherent Scatter Working Group (ISWG). The ISWG publishes these schedules as part of the International Geophysical Calendar. The link to the current schedule (as well as those for previous years) may be found at: http://people.ece.cornell.edu/wes/URSI_ISWG.

This report will include some facts about the World Days, how to request World Days for satisfying certain scientific objectives, and descriptions of the experiments carried out or yet planned for 2005.

World Day facts:

- World Days provide for coordinated operations of two or more of the incoherent scatter radars (ISRs) for common scientific objectives. (Experiments that require only 1 should be set up separately and directly with those in charge of that ISR.)
- World Days should be scattered throughout the calendar year.
- World Day data is to be promptly submitted to the CEDAR database and/or made available through other online databases as appropriate.
- The number of World Days per year has been increased to 58 this year which includes several normal runs of a few days plus one long run of 30 days.

World Day requests should:

- Outline the science objectives.
- Describe the measurements required to meet the science objectives (including a list of the parameters to be measured, the altitude, azimuth, and elevation ranges over which the measurements are to be made, and time resolutions, with the dates or seasons, number of days or hours, phase of the moon, etc.).
- List which ISRs and which instruments are to be included.
- Include the radar operating modes for each ISR.
- Name a point person for coordinating the details of the experiments.

2005 World Day observations

LTCS (Lower Thermosphere Coupling Study): Tidal Variability

After 17 years of collecting ISR data in the lower thermosphere under the LTCS (Lower Thermosphere Coupling Study) program, the basic structure of tides is relatively well understood with the most striking single property of atmospheric tides being the very large variability of tidal amplitudes. Possible sources for this variability include non-migrating tides, planetary waves, and geomagnetic influences. Now efforts must focus on the sources of this tidal variability and are conditioned on obtaining wind and temperature data from altitudes between 100 and ~130-140 km.

The program requires synoptic lower thermospheric observations during two intervals of 4-5 days each per year. The 30-day run (the "World Month") planned for 2005 will particularly address longer period waves, e.g., the 5 to 16-day waves. (See special note on this long run below.) We plan to coordinate the analysis of this data with SABER temperature data, TIDI mesospheric winds, and MF/meteor radar winds.

LTCS Contact: Larisa P. Goncharenko

M-I Coupling (Magnetosphere-Ionosphere Coupling): Storm and Substorm Effects on the Middle- and Low-Latitude Ionosphere

Magnetic storms and substorms are fundamental disturbances in the magnetosphere and can significantly increase, or decrease ionospheric electron densities (termed positive or negative storms, respectively). Electric fields originating in the magnetosphere can penetrate to the low-latitude ionosphere resulting in vertical motions that restructure the F-region density profiles due to the height dependence of the recombination rate. Substorm electric fields can change F-peak densities by 20-30% within one hour and correspondingly large changes also occur in TEC at low latitudes.

There are a number of outstanding problems with the effects of storms and substorms on the middle- and low-latitude ionosphere that remain unsolved.

· How much do magnetic storms affect the low-latitude ionosphere?
· How significant are the changes in TEC and *F*-region densities that result from penetrating magnetospheric substorm electric fields?
· How are changes in the low-latitude ionosphere coupled with the variations in the magnetosphere and solar wind?
· What processes are responsible for the ionospheric electron density disturbances?
· How do the disturbances in the electron density profiles and TEC vary with longitude and latitude?
· What are the atmospheric and dynamic processes at low latitudes during magnetic storms?

Radar chain measurements of the ionospheric plasma parameters (velocity, density, and temperature) are needed to solve, or partially solve, these problems. A magnetic storm generally lasts for 2-3 days. Periodic substorms often occur over a time interval of 10-30 hours during storms. Substorms evolve over 2-3 hours while penetration electric fields occur with times scales on the order of 30 minutes. The radar chain experiments should therefore last 5-7 days to include some quiet times before and after the storm, and have a reasonably high time resolution of 5-15 minutes.

Millstone Hill data from the M-I Coupling World Day of 2004 April 4 show factors of 2 to 3 increases in *F*-region electron densities. Unfortunately the SSC began just at the end of the regular World Day period and the other observatories missed the event, except for the Jicamarca Digisonde which did observe similar increases.

MI-Coupling Contact: Chaosong Huang

GPS-Radar (Global Plasma Structuring-Radar Experiment): Thermal plasma coupling between low, mid, and high latitudes

Recent multi-technique observations have shown that the equatorial ionosphere and inner plasmasphere are coupled from low to auroral latitudes by electric fields and plumes of storm enhanced electron densities which feed tongues of ionization into the polar caps. This global mechanism carries low-latitude dayside plasma into the nightside auroral ionosphere. These events cause significant space weather effects during major magnetic storms, but also occur during less-disturbed conditions.

Wide latitude coverage is needed to study such events and should include

· Measurements of plasma perturbations due to inner magnetospheric electric fields (Sonderstrom, EISCAT, Millstone Hill, SuperDARN)
· Topside observations (Arecibo and Jicamarca)
· Mid-latitude profiles (Kharkov and Irkutsk)
· Global GPS TEC imagery
· Particle precipitation and electric fields (DMSP)
· Plasmaspheric imagery (IMAGE)

Experiments should be conducted during the Spring and Fall Equinoxes for 2 full days with the moon down.

GPS-Radar Contact: John Foster

Meteoric Ions (Global observations of ionization created by the Perseids and Leonids)

During the 2002 Leonids, the EISCAT UHF radar detected enhanced ionization between 90 and 180 km with densities up to 3.3 x 10^11 m-3. No systematic study of such enhancements has yet been performed. Three-day runs for the Perseids (starting on August 10 at 0900 UT) and for the Leonids (starting on November 17 at 1600 UT) are suggested.

Meteoric Ions Contact: Ingemar Haggstrom

Synoptic

Synoptic experiments are intended to emphasize wide coverage of the F-region, with some augmented coverage of the topside or E-region to fill in areas of the databases that have relatively little data.

Synoptic Contact: Wes Swartz

C/NOFS (Communications / Navigation Outage Forecasting System)

The primary purpose of C/NOFS is to forecast the presence of ionospheric irregularities that adversely impact communication and navigation systems through

· improved understanding of the physical processes active in the background ionosphere and thermosphere in which plasma instabilities grow;
· the identification of those mechanisms that trigger or quench the plasma irregularities responsible for signal degradation; and
· determining how the plasma irregularities affect the propagation of electro-magnetic waves.

The C/NOFS satellite is to be launched into a low inclination (13°), elliptical (~ 400 x 700 km) orbit. It will be equipped with sensors that measure ambient and fluctuating electron densities, ion and electron temperatures, AC and DC electric fields, magnetic fields, neutral winds, ionospheric scintillations, and electron content along the lines of sight between C/NOFS and the Global Positioning System (GPS) satellite constellation. The orbit will have a 45-day repeating precession. Complementary ground-based measurements including the Jicamarca and Altair radars are also critical to the success of the mission. Calibration comparisons will be scheduled for local noon in Northern Spring/Summer 2005 and validation comparisons will be during local nighttime in Fall 2005 and Winter 2006. Requests for additional UAF radar time beyond the currently scheduled World Days are to be made directly to the respective observatory staffs once orbital characteristics are known.

C/NOFS Contacts: Odile de La Bedaujardiere, David Hysell, Wes Swartz

CPEA (Coupling Processes in the Equatorial Atmosphere)

This is an initiative for studying the coupling of dynamical coupling processes in the equatorial atmosphere from the troposphere up through the thermosphere and ionosphere centered around the Indonesian Equatorial Atmospheric Radar (EAR). Opportunities for collaborations initially focused on the successful March-April 2004 campaign period.

CPEA Contacts: Shoichiro Fukao, Project Leader, Sunanda Basu, Janet Kozyra

MST (Studies of the Mesosphere, Stratosphere, and Troposphere)

Coordinated *D*- and *E*-region campaigns where the ISR's and supporting instruments focus on their lower altitude capabilities. JRO uses a high resolution MST mode, while Arecibo uses a dual mode of *D*- and *E*-region drifts (with accompanying lidar & imaging measurements). The main interest is in obtaining gravity wave momentum fluxes. Minimum requirements would be winds with a time resolution of one or two minutes and a height resolution 450 meters or better. It may be possible to collect the lower atmospheric winds at Jicamarca with little or no adverse impact to the upper atmospheric/ionospheric measurements and may tie nicely in with the LTCS World Day periods.
MST Contacts: Gerald Lehmacher, Erhan Kudeki, Jorge L. Chau

World Month (Searching for Long Period Effects)

Studies of long period waves and tides require measurements over many sequential days. This 30-day run should provide an unprecedented data set for such studies. Experimental modes should emphasize the lower thermosphere as for the LTCS campaigns. It is anticipated that not all of the ISRs will be able to run for the full 30-day period, in which case only a "best effort" is asked for. For example, Sixto Gonzales of the Arecibo Observatory suggested that they could only run for about 10 of the 30 days, and these 10 may need to be in two groups of 5 days each. Labor or power saving modes may be adapted at some sites. For example, John Foster of Millstone Hill suggested that they would probably limit their runs to just the daytime hours. Further specific details are yet to be worked out.
WM Contacts: Larisa P. Goncharenko, and Wes Swartz

2.4 G4: Ionospheric Research to support radio systems

Chair: P. Wilkinson (Australia), Vice-Chair: M. Angling (United Kingdom)

URSI Commission G Working Group 4: Ionospheric Research to Support Radio Systems was formed at the Maastricht General Assembly with Dr Phil Wilkinson as the Chair and Dr Matthew Angling as Vice-Chair. The group has wide objectives, and seeks to maintain an overview of all ionospheric research related to radio systems. Those supporting the group felt that wider communications through a working group and an associated mailing list could enhance both our interests in these areas as well as advance the research in general. With this in mind, a website was set up at: http://www.ips.gov.au/IPSHosted/wg4/index.html.

The areas of general interest for the group are reflected in the website topic areas: meetings, useful links and contacts. The meetings section is intended to advertise meetings that are of general interest to members of the group, the useful links section is intended to bring together links to websites that are of general interest to the group. Although search engines can find sites rapidly, there are still advantages having specialist listings available.

A moderated mail list was established and currently has 144 members. In addition to a general information role, the group felt it was appropriate to sponsor at least two projects that were felt of general importance. The areas selected were data assimilation and propagation predictions for digital radio. Under the data assimilation section, a challenge was proposed. The challenge was to model the MUF for a European HF circuit by assimilating data available from the IGS databank into various models. The second project was intended to focus on propagation predictions for digital radio. The website was intended to form a discussion forum alongside the mail list.

Both the website and mail list were established in September 2004. However, activity since then has been slow. However, some initial comparisons of data assimilation models have been conducted by QinetiQ, Fusion Numerics and the University of Bath. Results have been reported in the proceedings of the Beacon Satellite Symposium (2004) and the Ionospheric Effects Symposium (2005). Further informal discussions were held at IES and it is hoped that additional comparative testing will be undertaken.

Although the group has not been as active as hoped, it fills an important gap in the Commission G spectrum and we recommend it continue for a further triennium.

2.5 GF: Middle atmosphere

Co-Chair for Commission G: J. Röttger (Germany), Co-Chair for Commission F: C.H. Liu (China, SRS)

The Proceedings of the 9th International Workshop on Technical and Scientific Aspects of MST Radar were published by SCOSTEP and MeteoFrance in October 2000, and in the special issue of the journal Annales Geophysicae, vol. 19, No. 8, 2001.

In November 2000, a 2-weeks course was held at the International Centre for Theoretical Physics in Trieste (ICTP) on "Physics of Mesosphere-Stratosphere-Troposphere Interactions with Special Emphasis on MST Radar Techniques", which was also devoted to activities of URSI WG GF1, and J. Röttger et al. were lecturers.

In July 2001 the Tenth International EISCAT Workshop was held in Tokyo, Japan, and in August 2003 the Eleventh International EISCAT Workshop was held in California, USA. Several papers were directed to coupling and research of the middle atmosphere with radio methods, which is the subject of URSI Working Group GF1.

During three weeks in November and December 2002 the Third International School on Atmospheric Radar, ISAR-3, was held at the International Center of Theoretical Physics in Trieste. J. Röttger, together with D.N. Rao of India and S. Radicella of ICTP were directing this school, which allowed young scientists to become acquainted with the radar and radio techniques used for middle and lower atmosphere research. Some financial support had been allocated by URSI.

J. Röttger was chairing the International Steering Committee of the Tenth Workshop on Technical and Scientific Aspects of MST Radar, MST-10, which was held in May 2003 in Piura, Peru. Sponsorship and financial support from URSI was granted. Preparations and performance of this workshop were part of the URSI WG GF1 work. A significant part of this workshop dealt with lectures, reports and outlines of new techniques, methods and science for radio/radar studies of the middle and lower atmosphere. The Proceedings of the 10th International Workshop on Technical and Scientific Aspects of MST Radar were published by the Universidad de Piura and the Radio Observatorio de Jicamarca, Instituto Geofisico del Peru in December 2003, and a special issue of the Journal Annales Geophysicae was published in 2004.

The EISCAT Scientific Association had established a committee on defining the needs and future directions for the coming decades for scientific research of the Earth's ionosphere, magnetosphere and atmosphere. J Röttger is member in this committee and a member in the EISCAT Council.

In early 2004 a new project was launched during a colloquium, held end January 2005 in Tirupati, India: The International Network on Tropical Atmosphere Radar – INTAR - will help to coordinate radar observations in low latitude regions and foster cooperation and exchange programs between facilities and observatories in the tropical and extra-tropical region. The activities of WG GF1 are related to this new project. J. Röttger is Chairman of the International Steering Committee of INTAR.

In summary, the Working Group GF1 "Middle Atmosphere" again has had a successful triennium and the continuation of this URSI Working Group GF1 is requested, since we are in the process of preparing the 11th International Workshop on Technical Aspects of MST Radar, MST-11, to be held in Australia and are establishing a permanent International School on Atmospheric Radar, where sponsorship by URSI and other organizations will be most helpful.

2.6 GH1: Active experiments in plasmas

Co-Chair for Commission G: Sa. Basu (USA), Co-Chair for Commission H: T. Leyser (Sweden) / Bo Thide (Sweden)

The Working Group on Active Experiments in Plasmas reports enthusiastic support to its Call for Papers for this XXVIIIth URSI General Assembly. A session entitled, "Ionospheric Modification by High Power Radio Waves: Coupling of Plasma Processes" has been organized that features 10 oral presentations from leading international experts in this field of Radio Science and a further 4 papers, that could not be accommodated in the oral session, have been scheduled in the poster session.

During the period under review (August 2002 to October 2005) the Working Group reports active international cooperation in this field resulting in several breakthroughs in the area of interaction between the ionospheric plasma and high power high frequency radio waves. Research has been performed at the EISCAT, Sura and HAARP ionospheric modification facilities located in Norway, Russia, and Alaska, USA respectively. The EISCAT HF facility has distinguished itself by fostering collaborative research with scientific groups from U.K., Finland, Sweden, Germany, Japan, and Russia.

During the period under review the artificial optical emissions induced by HF pumping at harmonics of electron gyro-frequency have been intensively studied at all three facilities mentioned above. At EISCAT, it was demonstrated that the upper hybrid waves are important in accelerating the electrons, which are the source of artificial optical emissions in the F-layer. By performing optical measurements at multiple wavelengths the pump accelerated electron energy spectrum has been established for the first time. It was discovered that the pump wave with appropriate modulation could increase the strength of Polar Mesospheric Summer Echoes (PMSE) as observed by the UHF radar at 224 MHz. It holds the promise of a diagnostic for the dusty mesosphere. The modification experiments in Sura, Russia have been supported by an array of ground diagnostics that included the backscatter receivers including UTR-2 in the Ukraine. At Sura, the radio wave induced red OH Meinel band emission has been discovered and attributed to focusing by weak sporadic ionization near 80-85 km. Further, the broadening of the spectrum of the artificial ionospheric turbulence has been detected when the pump frequency was close to the fourth harmonic of the electron gyro-frequency. Alfven wave generation has been attempted at both EISCAT and Sura by the use of modulated pump wave and by directing the pump wave along the geomagnetic field.

The High Frequency Active Research Program (HAARP), a major high power HF wave facility in Gakona, Alaska is nearing completion. The facility is currently operated with the maximum effective radiated power of 0.96 GW and it will attain 3.6 GW level when completed. The HAARP facility will be supported by an array of ground-based diagnostics that will include incoherent scatter radar, ELF/VLF receivers, optical imagers and VHF radar. At both the EISCAT and HAARP facilities, it has been established that when the pump beam is pointed south of the zenith the optical emission tends to appear on or close to the magnetic zenith. This magnetic zenith effect has recently been confirmed by observations at the Sura facility. At HAARP it has been observed that the optical emission is dramatically enhanced when the pump frequency is close to the second harmonic of the electron gyro-frequency. The SuperDARN radar in Alaska and the Advanced Modular Incoherent Scatter Radar (AMISR) observations show that at this time the upper-hybrid resonance and Langmuir turbulence can coexist and this may account for the intense optical emission.

A new high power HF facility, Space Plasma Exploration by Active Radar (SPEAR), is being deployed on Spitzbergen in the Svalbard archipelago. The principal capabilities of SPEAR will include the generation of artificial irregularities, operation as an all-sky HF radar, and remote sounding of the magnetosphere. SPEAR being located near the cusp region at the boundary of the open- and closed field line boundary will provide a unique opportunity for exciting polar cap plasma physics experiments. Overall, this area of research is poised for important breakthroughs and discoveries in the coming years.

The group wishes to continue as an URSI Working Group in the forthcoming triennium.

2.7 GHC: Wave and turbulence analysis

Co-Chair for Commission G: D. Hysell (USA), Co-Chair for Commission H: T. Dudok de Wit (France), Co-Chair for Commission C: G Kubin (Austria)

The HGC working group was created more than a decade ago with the aim to foster interactions between different communities that were applying the same techniques (nonlinear wave and turbulence analysis techniques) in different contexts. This group played an important role in disseminating knowledge about novel concepts. Its main activity consisted in organising multidisciplinary workshops + a session at each general assembly.

Two major actions were taken during the 2001-2005 period:

1. In September 2001, members of the working group organised a one-week summer school on Analysis techniques for space plasma data in La Londe (French Riviera). This summer school was attended by 70, mostly European students. The number of applications we received was more than twice that number, which confirms the large demand fur such topics. The school mainly consisted of lectures given by specialists and some computer sessions. Some of the topics were : spectral analysis, multiscale analysis, multipoint data, statistical analysis of urbulence, nonlinear transfer functions, . . .
   This school was hosted by the french national research agency CNRS but was also supported by URSI commission H.
   The documents of the school can still be accessed at the address http://lpce.cnrs-orleans.fr/~ddwit/lalonde/
2. In May 2004, members of the working group organized a two-week workshop on Data analysis techniques for multipoint magnetospheric missions in Beijing. This was the third of a series of capacity building workshops that are hosted by COSPAR; their objective is to provide intensive training to a selected team of young and bright students from developing countries.
   Attendance was limited to 25 students, who mostly came from China, India and Eastern Russia. Lectures were delivered by scientists from the international community. The programme included lectures in the morning and hands-on computer sessions in the afternoon. Most topics were related to multipoint missions, and in particular to the ongoing Chinese Double Star mission.
   The organisation of such a workshop was a new and very rewarding experience. We are confident that most of the students will greatly benefit from the contacts that were established during that intensive two-week training. We also believe that this formula could easily be adapted to other regions, such as India or Eastern Europe, with adapted topics such as Space Weather.

The cost per student of such a workshop is quite high (about 2600 $ / student) since there is no registration or accomodation fee, and financial travel support is provided to all. This high level of support, however, has turned out to be essential to guarantee access to all.

This school was hosted by COSPAR but was also generously supported by the URSI board. The documents of the school can still be accessed at the address http://www.faculty.iu-bremen.de/jvogt/cospar/cbw3/

As for the future evolution of this HGC working group, we believe that its relevance it not so clear anymore, even though the topics it addresses remain pertinent. Indeed, the interest for turbulence analysis (and associated microphysics) has decreased. Several of topics that were initially addressed by this WG only, have now become part of the programme of other sessions. Therefore, we suggest to bring this WG to an end, with the hope that other pluridisciplinary actions will emerge.

2.8 URSI/COSPAR on International Reference Ionosphere (IRI)

Chair : B.W. Reinisch (USA), Vice Chair for COSPAR : Martin Friedrich (Austria), Vice Chair for URSI: Lida Triskova (Czech Republic); Secretary: D. Bilitza (USA),

International collaborations continued within the International Reference Ionosphere (IRI) project. Current work focuses on improvements of the topside electron density profiles, using data from the ISIS and Intercosmos 19 topside sounders, and on the development of a model describing the monthly variability of ionospheric characteristics. These are the main topics of the IRI Task Force Activities held annually at the Abdus Salam International Center for Theoretical Physics (ICTP) in Trieste, Italy. The proceedings of these meetings are published as ICTP Reports (e.g., IC/IR/2002/23, IC/IR/2003/7, IC/IR/2004/1). Selected papers from the 2001 IRI Workshop in Sao Jose dos Campos, Brazil, were published in a dedicated issue of Advances in Space Research (Volume 31, Number 3, 2003) entitled “Description of the Low Latitude and Equatorial Ionosphere in the International Reference Ionosphere”. The 37 papers provide a good overview of ongoing modeling and measurement efforts in the low latitude ionosphere with special emphasis on the South-American sector.

During the 2002 World Space Congress and COSPAR General Assembly in Houston, Texas, the IRI team conducted a 2-day session on the “Path Toward Improved Ionosphere Specification and Forecast Models”. Most of the 40 presentations are published in Advances in Space Research, Volume 33, Number 6, 2004. New models were presented for the topside ion composition (Triskova et al., using AE-C and IC-24 data), for the topside electron density profile (Bilitza, using ISIS data), for the plasmaspheric electron density distribution (Huang et al., using IMAGE/RPI data), for temperature profiles (Kutiev et al., using AKEBONO data), and for the D-region densities (Friedrich et al., using EISCAT data).

The 2003 IRI Workshop was held at Rhodes University in Grahamstown, South Africa, with support from COSPAR, URSI Commissions G and H, the US National Science Foundation, ICTP, and several local organizations including Rhodes University, the Hermann Ohlthaver Institute for Aeronomy (HOIA), the South African National Research Foundation (NRF), and the Grintek Ewation Company. About 40 scientists participated in the week-long meeting and discussed future improvements and enhancement of IRI with special emphasis on "Quantifying Ionospheric Variability". Participants also discussed concerns regarding the data quality of groundbased ionosonde data archived in the World Data Centers. Noting the importance of such data for studying long-term trends, Prof. Reinisch as chair of IRI sent a letter to the World Data Center in Boulder, CO.

In October 2003, the IRI group organized a day-long session during the German National URSI Meeting in Kleinheubach/Miltenberg in honor of Prof. Karl Rawer's 90th birthday. K. Rawer was the first Chairman of the IRI Working Group and has continued to strongly support and promote the IRI effort. Papers presented during this session were published in Advances in Radio Science – Kleinheubacher Berichte.

A very successful two day session on "Modeling of Ionospheric Temperatures and Ion Composition' was organized by the IRI Working Group during the 2004 COSPAR General Assembly in Paris, France (July 18-24). Papers are now being reviewed for inclusion a special issue of Advances in Space Research.

Improvements of the IRI model at equatorial latitudes in the African sector were studied in the framework of an NSF- and Fulbright-supported visits of Dr. Olivier Obrou (University of Cocody, Abidjan, Ivory Coast) and Prof. Jacob Adeniyi (Universiytyt of Ilorin, Ilorin, Nigeria) at NASA's Goddard Space Flight Center working with Dr. Dieter Bilitza. The results will benefit the representation of ionospheric variability and of F-peak parameters in IRI for the African region.

The IRI Workshop 2005 will be part of the centennial celebration of the Ebro Observatory in Roquestes, Spain. The meeting chaired by Dr. David Altadill will be held from June 27 to July 1 and will focus on "New satellite and ground data for IRI, and comparison with regional models" (homepage at http://www.obsebre.es/w3/wsiri/).

2.9 Other Working Groups

Other Working Groups in which Commission G is active are reported on the lead Commission reports. These include:

- Inter-commission Working Group on Solar Power Satellites
  Co-Chair for Commission G: M. Rietveld (Norway)
- EGH: Seismo Electromagnetics (Lithosphere-Atmosphere-Ionosphere Coupling)
  Co-Chair for Commission G: S. Pulinets (Russia)
- FG: Atmospheric Remote Sensing using Satellite Navigation Systems
  Co-Chair for Commission G: C. Mitchell (United Kingdom)
- HGEJ: Supercomputing in Space Radio Science
  Co-Chair for Commission G: A. Barakat (USA)
- URSI/IAGA VLF/ELF remote Sensing of the Ionosphere and Magnetosphere (VERSIM)
  Co-Chair for Commission G: M. Parrot (France)
  The Working Group report appears in the commission H report

3. Sponsored meetings

3.1 Mode A sponsorship

Commission G offered Mode A (no additional funds) support to the following meetings:

- **Getting the Most out of the Radio Spectrum**, London, United Kingdom, 12-25 October 2002
- **STAMMS** – Spatio-Temporal Analysis and Multipoint Measurements in Space, Orléans, France, 12-16 May 2003
- **Atmospheric Remote Sensing Using Satellite Navigation Systems** (URSI Joint Working Group FG), Matera, Italy, 13-15 October 2003
- **WARS04** (Workshop on Applications of Radio Science) conference, Hobbart, Australia, 18-20 February 2004
- **COSPAR Capacity Building Workshop**: Analysis of Data from Multisatellite Magnetospheric Missions, Beijing, China, 3-14 May 2004
- **African Regional Workshop**, Nairobi, Kenya, 16-20 August 2004
- **Radar 2004**, Toulouse, France, 19-21 October 2004
- Internatioanl School / Symposium for Space Simulations, Kyoto, Japan, 26-31 March 2005
- **2005 Ionospheric Effects Symposium – IES 2005**, Alexandria, Virginia, 10-12 May 2005-06-16

3.2 Mode B sponsorship

Meetings sponsored under Mode B received seed funding from Commission G, and other Commissions in some cases.

- **COSPAR 2002 / IRI Session**
  Full report: The Radio Science Bulletin, December 2002, p. 61
  The 34th COSPAR congress was held in Houston, USA. The IRI session, held on 17-18 October, reviewed ongoing ionospheric modelling activities, with a special emphasis on efforts that involve the IRI model.
- **ISAR-3**
  Full report: The Radio Science Bulletin, June 2003, p. 50
  The 3rd International School on Atmospheric Radar was held in Trieste, Italy, 25 November – 13 December 2002. 28 participants from 17, mostly developing countries, attended the school.
- **MST-10**
  Full report: The Radio Science Bulletin, September 2003, p. 57
  The 10th International Workshop on Technical and Scientific Aspects of MST Radar was held 13-20 May 2003 at the campus of Universidad de Piura in Peru. A

total of 109 oral papers (24 thereof invited) and 66 poster papers were presented.

- **IRI 2003 Workshop**
  The International Reference Ionosphere (IRI) Working Group held their annual workshop in 2003 at Rhodes University in Grahamstown, South Africa from 6 to 10 October. A total of 30 delegates representing 13 different countries attended the 5-day meeting presenting a total of 38 papers. The theme of IRI 2003 was "Ionospheric Variability" and 12 papers were presented covering this topic.
- **Vertical Coupling in the Atmsosphere / Ionosphere System**
  Full report: The Radio Science Bulletin, September 2004, p. 115
  The 2nd IAGA/ICMA workshop on Vertical Coupling in the Atmosphere / Ionosphere System was held in Bath, UK, on July 12-15, 2004. It was attended by 65 scientists from 19 countries. The participants presented 60 papers, from which 9 were solicited
- **COSPAR 2004 / IRI Session**
  Full report: The Radio Science Bulletin, December 2004, p. 110
  The session, held during the COSPAR congress held 18-25 July 2004 in Paris, was organized by the IRI Working Group with the goal of improving the description of the electron and ion temperature and the ion composition in the IRI model.
- **NATO Advanced Study Institute on Sprites, Elves and Intense Lightning Discharges**
  The meeting was held at Corte University, France on 21-30 July 2004. No report is available at the time of writing.
- **AP/RASC 2004**
  The Asia-Pacific Radio Science Conference was held 20-23 August 2004 in Beijing, China. No report is available at the time of writing.
- **IRI 2005 Workshop**
  Full report: The Radio Science Bulletin, June 2005, p. 82.
  The IRI 2005 workshop was held 27 June – 1 July at the Ebro Observatory in Roquetes, Spain.

COMMISSION J

This triennium report was prepared by Prof. Inoue, Commission J Chair 2002-2005.

1. Scientific Activities

The Wilkinson Microwave Anisotropy Probe (WMAP) has made the detailed full-sky map of the oldest light in the universe. WMAP detected anisotropies at a level of roughly 10^{-5} on scales of tens of arcminutes to several degrees in the microwave background radiation of the Universe, and the age of the Universe is shown to be 13.7 billion years with an accuracy of 1%. Furthermore, many cosmological parameters such as the geometry and contents of the Universe were derived in detail (http://map.gsfc.nasa.gov/m_mm.html). Follow-up and more deep observations have been done. The nature of Gamma Ray Burst (GRB) has been investigated by coordinated observations from gamma-ray to radio resumes. GRB has been understood that in some kind of a massive star explosion, the energy is concentrated into the narrow beam to be seen as GRB. Studies of binary system have been made: a double pulsar system was found to allow high precision tests of general relativity, and binary black hole system is searched to investigate evolution of massive black hole in AGNs.

2. Engineering/Technical Developments

The Atacama Large Millimeter Array (ALMA) project is an international astronomy facility and an equal partnership between Europe and North America, in cooperation with the Republic of Chile. ALMA is funded in North America by the U.S. National Science Foundation (NSF) in cooperation with the National Research Council of Canada (NRC), and in Europe by the European Southern Observatory (ESO) and Spain (http://www.alma.info/). The National Astronomical Observatory of Japan (NAOJ) and the radio astronomy research community in Japan joined to form the Extended ALMA with the Atacama Compact Array (ACA), receiver production, the ACA correlator etc.

LOFAR (Low Frequency ARray) started its construction in the Netherlands. LOFAR is an array of simple omni-directional antennas instead of mechanical signal processing with a dish antenna. The electronic signals from the antennas are digitised, transported to a central digital processor, and combined in software to emulate a conventional antenna, operational at frequencies below 250 MHz (http://www.lofar.org/).

The Square Kilometre Array (SKA) project has made substantial progress in many areas, from science to technical to organizational. The science case was published as 49 refereed papers in a special issue of New Astronomy Reviews Vol. 48 in December 2004. Proposals for siting the SKA are in preparation in four countries, and RFI monitoring is being carried out. A series of papers on the technology to be employed in the SKA have been published in a special issue of Experimental Astronomy, Vol. 17. Funding has been obtained for a major SKA design study in Europe, and for SKA Pathfinder telescopes in Australia and South Africa. The International SKA Project Office has been established to coordinate the international efforts (http://www.skatelescope.org).

The rapid advance of both data-transmission technology and signal-processing technology over the past few years is responsible for dramatic increases in the power and sophistication of signal transport and analysis. This technology allows more data to be transmitted further, faster, and with more power, stability and reliability than was ever before possible. The encapsulation of much of this power into field-programmable gate arrays (FPGAs) has also led to unprecedented flexibility as well, helping to greatly reduce design and testing times, and allows hardware to be re-used for diverse sets of needs and applications.

Thanks to these developments, extensions to wideband systems have been made in several telescope systems. These are the Expanded Very Large Array Project (EVLA: http://www.aoc.nrao.edu/evla/) and e-MERLIN (http://www.jb.man.ac.uk/research/rflabs/eMERLIN.html), which are up-grade of the existing interferometer array systems.

3. Report on Resolutions

U1 - International Radio Quiet Reserves

Objectives:
To investigate the desirability and the issues involved in establishing International Radio Quiet Reserves for future radio astronomy.

Background:
Radio telescopes are sensitive to man-made radio frequency interference and it is desirable to minimize the effects of RFI by establishing mitigation strategies and processes. Radio quiet zones have come out as the most powerful and natural approach to optimize the observational conditions.

What was done and by whom since GA 2002:
Most recently a taskforce on regulatory issues on the Square Kilometre Array has been established and has drafted a memorandum on these issues. IUCAF through its participation in ITR-R study group 7 has established a question to study the properties and characterization of Radio Quiet reserves. The OECD Global Science Forum through the Taskforce on Radio astronomy and the Radio Spectrum has published a Report in February 2004 resulting in 4 recommendations including the establishment of a small number of "…zones on the ground where future radio observatories could be located and within which satellite emissions could be controlled."

The outcome:
The series of international workshops on Radio Frequency Interference Mitigation Strategies was continued at a two day workshop in Penticton, Canada in July 2004. Preparation for the JA-session "Radio Frequency Interference; Problems and Solutions" to be held in at the next, 2005, URSI-GA in Delhi, is in progress.

U2 - Establishment of a working group on the possible redefinition of UTC

Objective:
To survey URSI membership and determine what affect a redefinition of UTC would have on their systems

Background:
The ITU is considering a redefinition of UTC so as to eliminate leap seconds, which cause confusion. As part of its deliberations, it had asked several international bodies, including URSI, to let them know what objections or other considerations they may have.

What was done and by whom:
A Commission J Working group surveyed URSI and the general public, and presented a report at the 2002 General Assembly. An URSI-wide resolution was passed then, and a new Working Group was formed which again surveyed the general membership and prepared a resolution.

The outcome:
The resolution, submitted for consideration at the 2005 GA, notes that no substantive response was received from URSI members and calls for the ITU to be informed that URSI has no objection to a change in UTC, but also does not endorse such a change.

4. National Report on Highlights and Topics

Report from Australia by Ray P. Norris

1. The Australia Telescope Compact Array has been upgraded to operate at 3 and 12 mm, and has produced a number of exciting results at both wavelength bands. These include the detection of CO in the most distant known radio galaxy, at a redshift of 5.2. See http://www.atnf.csiro.au/research/highlights/2004/klamer/klamer.html for more details.
2. The Australian contribution to the SKA has been focused into the development of a New Technology Demonstrator to be developed at a radio-quiet site in Western Australia. See http://www.atnf.csiro.au/projects/ska/ for more details.

Report from France by Gerard Beaudin and Thibaut Le Bertre

Summary of activities:

- scientific activities: exploitation of ground-based instruments (IRAM, RD + cosmic ray air shower experiment, RH, RT), and space-borne instruments (radar on CASSINI, ODIN)
- protection of radio frequencies from 20 MHz to 300 GHz (1.5 man year in organisms such as C6, ANF, CRAF, IUT),
- preparation to the international projects (SKA, FASR, LOFAR) : developments of ASICs (front end) and EMBRACE demonstrator for SKA ; RFI mitigation (real time algorithms that are tested on the Nançay instruments),
- preparation for mm and sub-mm instruments (ALMA, Herschel, Planck): algorithms, detectors, spectrometers, correlators, etc.
- members of com. J are also involved in teaching radio techniques and applications in various universities.

Report from Germany by Ernst Fuerst

Most important for Commission J in Germany was the beginning of astronomical operation of the APEX telescope. Also money was granted to change the current sub-reflector of the 100-m.RT by a new one with an active surface, to compensate for the remaining distortion of the main dish (not perfect homology). Currently we are planning to establish LOFAR stations at various places in Germany, among them the 100-m RT site and AIP Potsdam. Along with this, mainly argued by e-VLBI, it is planned to connect the 100-m-RT with the main institute in Bonn by a 10 Gbit/s fiber link.

Progress in China by Yihua Yan

For Chinese Lunar Exploration Mission and future Chinese VLBI network, a 50m antenna in Miyun Radio Astronomical Station of NAOC, Beijing and a 40m antenna in Yunnan Observatory of NAOC are under construction in 2005. For the future FAST (Five-hundred-metre Aperture Spherical Telescope), being as the demonstrator of the Chinese SKA (Square Kilometre Array) concept, its scaled model of 30m is being built at Miyun station. For future generation telescopes, the site survey looking for best potential sites is being conducted by NAOC. An array (21CMA) of ~100 elements with each of 127 logarithmic periodic dipole antennas in 70-200MHz range is being built (30 of such elements have been constructed in 2005) in Xinjiang, aiming at observing the highest redshift of the 21 cm HI line. A Chinese Spectral Radioheliograph in dm-cm wave range (CSRH) with ~100 antennas of 2-3 m in diameter is proposed with a potential radio quiet site in Inner Mongolia and a 2-element prototype interferometer has been developed and tested. The development of different techniques in wide wavelengths in radio astronomy, such as VLBI broadband digital correlators, superconducting mixers at sub-mm wavelengths and development of a compact 500 GHz SIS receiver have been conducted.

Report from Hungary by Istvan Fejes

The most distant radio-loud quasar known at present (z=5.8) the sub-mJy radio source SDSS J0836+0054, has been imaged with the European Very Long Baseline Interferometry Network at 1.6 and 5 GHz. The quasar at this early cosmological epoch appeared surprisingly “normal”, its radio emission is confined within the central 40 pc.

Report from Japan by INOUE Makoto

Several new observing systems have been operational, particularly in Universities. We formally participated in the ALMA project and began construction. A space mission is waiting for the launch to the Moon, and the second Space VLBI project has been proposed. The organization system of National Universities and Institutes was largely changed to agencies, and the effects are not yet understood.

The National Committee of URSI publishes and distributes the National Report at every URSI GAs, and the Report of National Commission J is included in it. The report is also seen in the National Commission J web site at http://vsop.mtk.nao.ac.jp/URSI/CommJJ.html, which is in the ‘Link to National Committees’ of the URSI Commission J web site (http://vsop.mtk.nao.ac.jp/URSI/).

Report from Norway by Per B. Lilje

Most of the work in Norway within radio astronomy has concerned space borne CMB experiments, notably development of new data analysis methods for Gaussianity testing, component separation and power spectrum estimation. These methods have been applied to the data from the COBE-DMR experiment and the Wilkinson Microwave Anisotropy Probe (WMAP), and will in the future be applied to the Planck data. Norwegian astronomers have been co-discoverers of anisotropies and non-gaussianities in the WMAP data that have caused wide interest. Norwegian astronomers have also taken part in the development of the LFI instrument of the Planck satellite. Norwegian chemists have taken part in radio astronomical discoveries of the new interstellar aldehyds propenal and propanal and have studied gas-phase formation of methyl formate in an astrophysical setting. Norwegian physicists have also studied properities of radar echoes from meteor trails.

Report from Peru by Walter R. Guevara Day

1. Instrumentation and site searching .
   Work has started to search for an Astronomical Site for visible, IR and radio bands in the south Peruvian montains (over 4500 m).
2. Educational.
   We (CONIDA and UNMSM) have started lectures about topics in astronomy and radioastronomy at pre-graduate level around our country. We need some help the international institutes for development of radioastronomy in our country with Visiting lecturer program for post-graduate level astronomy and instrumentation.

Report from UK by Jim Cohen

Double Pulsar:

An international team of scientists from the Jodrell Bank Observatory in the UK and from Australia, Italy, India and the USA have discovered the first double pulsar system (Lyne et al., Science 8 January 2004). Orbiting the 23-millisecond pulsar PSR J0737-3039A is a companion pulsar PSR J0737-3039B, rotating once every 2.8 seconds and orbiting PSR J0737-3039A in only 2.4 hours. The orbit is shrinking by 7mm per day, and the pair will merge in about 85 million years. The double pulsar will allow new high precision tests of general relativity.

e-MERLIN:

Work is well underway on upgrading the MERLIN interferometer network. The telescopes are now connected by dedicated optical fibres which carry a maximum bandwidth of 2 GHz in each of two polarizations from each of the 5 remote telescopes to Jodrell Bank Observatory. The wideband correlator to process the data is being built at Penticton by the National Research Council of Canada and will be delivered in 2006/7.

COMMISSION K

This triennium report was prepared Prof. Bernard Veyret, Commission K Chair 2002-2005.

In the last three years, Commission K has been very active in publishing articles in the RSB, sponsoring and organising scientific meetings and preparing for the General Assembly of Delhi (6 specific sessions and 3 shared sessions). It also shared the preparation of the white paper on SPS (Prof. J. Lin).

Several small meetings of national representatives of Commission K were organised during the scientific meetings of BEMS[1] and EBEA[2].

A close relationship was kept with WHO and in particular with the International EMF project as part of the liaison activity of Commission K within the SCT.

Radio Science Bulletin

The following papers have been edited by vice-chairman F. Prato and published in RSB:

1. Naomi M Shupak, Frank S Prato, Alex W Thomas. *Therapeutic Uses of Pulsed Magnetic-Field Exposure: A Review.* Dec 2003. 9-32
2. Stefan Engstrom. *Physical Mechanisms of Non-Thermal Extremely Low Frequency Magnetic-Field Effects*. Dec 2004. 95-106

The following paper has been edited and will be published soon in RSB:

3. Anders Ahlbom, Maria Feychting, Stefan Lönn. *Mobile phones and tumor risk: Interpretation of recent results*.

The following manuscript will be submitted in September 2005:

4. James Lin. *Review on BBB permeability and exposure to ELF and RF*.

Scientific Meetings

The following meetings have been sponsored by Commission K:

1. **EMF and Cardiac Pacemakers and Defibrillators**, Paris, France, 25 October 2002.
2. **JINA 2002**, Nice, France, 12-14 November 2002.
3. **APMC'02**: Asia-Pacific Microwave Conference, Kyoto, Japan, 19-22 November 2002.
4. **EMC Zurich 2003**, Zurich, Switzerland, 18-20 February 2003.
5. **ISMOT 2003** - 9th Int. Symp. On Microwave and Optical Technology, Ostrava, Czech Republic, 11-15 August 2003.
6. **International NIR Workshop and Symposium**, ICNIRP/URSI(K)/WHO, Seville, Spain, 20-24 May 2004.
7. **MSMW'04**, Fifth Int. Kharkov Symposium on Physics and Eng of Microwaves, mm and Submm Waves, Kharkov, Ukraine, 21-26 June 2004.
8. **EMC Wroclaw 2004**, Wroclaw, Poland, 29 June - 1 July 2004
9. **AP-RASC 04**: 2004 Asia-Pacific Radio Science Conference, Beijing, China, 20-23 August 2004.
10. **Radar 2004**, Toulouse, France, 19 - 21 October 2004.
11. **JINA-04**, Nice, France, 8-10 November 2004.
12. **EMC Zurich 2005**, Zurich, Switzerland, 15-17 February 2005.
13. **CEFBIOS 2005** - Coherence and electromagnetic fields in biological systems, Prague, Czech Republic, 1-4 July 2005.
14. **ISMOT 2005** - 10th International Symposium on Microwave and Optical Technology, Fukuoka, Japan, 22-25 August 2005.
15. **International Workshop on Electromagnetic Fields at the Workplaces**, Warsaw, Poland, 5-7 September 2005.

All of the funds available to Commission K went into the organisation of the Symposium held jointly with ICNIRP[3] and WHO[4]. It gathered more that 250 participants from all over the world and was a major success in terms of attendance (more that 250 participants) and scientific quality. One of the main contributions of Commission K was to organise the sessions on medical applications and on MRI and TMS[5].

[1] Bioelectromagnetics Society
[2] European Bioelectromagnetics Association
[3] International Commission on Non Ionizing Radio Protection
[4] International EMF project
[5] Transcranial Magnetic Stimulation

XXVIIIth General Assembly

NEWLY ELECTED OFFICERS, 2005-2008 TRIENNIUM

Following the elections at the XXVIIIth General Assembly in New Delhi, India, the Officers of the Board and the Scientific Commissions for the 2005-2008 triennium are as given below:

Board 2005-2008

President: François Lefeuvre (France)
Vice-Presidents:
- Gert Brussaard (Netherlands) (Treasurer)
- Chalmers M. Butler (USA)
- Martti M. Hallikainen (Finland)
- Phil H. Wilkinson (Australia)

Secretary General: Paul Lagasse (Belgium)
Past President: Kristian Schlegel (Germany)

Chairs 2005-2008

Commission A: Stuart Pollit (UK)
Commission B: Lotfollah Shafai (Canada)
Commission C: Andreas F. Molisch (USA)
Commission D: Frédérique de Fornel (France)
Commission E: Flavio G. Canavero (Italy)
Commission F: Piotr Sobieski (Belgium)
Commission G: Paul Cannon (UK)
Commission H: Richard Horne (UK)
Commission J: Richard Schilizzi (Netherlands)
Commission K: Frank Prato (Canada)

Vice-Chairs 2005-2008

Commission A: Paraneswar Banerjee (India)
Commission B: Karl J. Langenberg (Germany)
Commission C: Takashi Ohira (Japan)
Commission D: Franz Kaertner (USA)
Commission E: Christos Christopoulos (UK)
Commission F: Madhukar Chandra (Germany)
Commission G: Michael Rietveld (Norway)
Commission H: Yoshiharu Omura (Japan)
Commission J: Subra Ananthakrishnan (India)
Commission K: Guglielmo D'Inzeo (Italy)

The next URSI General Assembly will be held in Chicago, Illinois, USA, from 7-16 August 2008.

UNION RESOLUTIONS ADOPTED AT THE NEW DELHI GENERAL ASSEMBLY

U.1 Regional Coordination Initiatives

The URSI Council:

Considering
1. The existing initiatives, under the aegis of URSI national Member Committees, of Radio Science regional co-ordination (e.g. in North America, Asia-Pacific and Europe); and
2. That these initiatives are fully in accord with the URSI objectives; and
3. That these regional co-ordination committees would facilitate both the organisation and publicising of URSI activities and the dissemination of its recommendations and resolutions about scientific matters to national and supranational bodies

Resolve
To welcome and to encourage these initiatives.

Recommend
To the URSI national Member Committees to keep the URSI Board informed of the advancement of these initiatives.

U.1 Initiatives de coordination régionale

Le Conseil de l'URSI

Considérant :
1. L'existence d'initiatives, sous l'égide de Comités nationaux membres de l'URSI, de coordination régionale en Radio Science (par exemple en Amérique du Nord, en Asie-Pacifique et en Europe) ; et
2. Que ces initiatives participent pleinement des objectifs de l'URSI ; et
3. Que ces comités de coordination régionale devraient faciliter à la fois l'organisation et l'information des activités scientifiques de l'URSI et la diffusion de ses recommandations et résolutions auprès des instances nationales et supranationales ;

Décide
D'accueillir favorablement et d'encourager ces initiatives.

Recommande
Aux Comités membres concernés de tenir informé le Bureau de l'URSI de l'évolution de ces initiatives.

U.2 Solar Power Satellite

The URSI Council,

Considering
1. That meeting the world's energy needs, without considerable negative environmental effects, is one of the major challenges to sustainable development; and
2. The potential interest in collecting the Sun's energy in space and transmitting it through electromagnetic waves (microwaves) to the ground, and feeding it to the terrestrial power grid; and
3. That preliminary studies performed by radio scientists have evaluated the feasibility of Solar Power Satellite systems for such purposes, identifying potential benefits and problems;

Resolves
That URSI sees its role as providing the necessary scientific background and a fair and open forum on the technical issues of Solar Power Satellite systems; and

Recommends
That the *URSI White Paper on Solar Power Satellite Systems* should be used as a reference to undertake world-wide coordinated studies to investigate the potential of Solar Power Satellites as an alternative energy source, taking into account all relevant scientific aspects, the environmental and societal impact, the impact on other radio services, and the technical and economic feasibility.

U.2 Centrales solaires en orbite

Le Conseil de l'URSI,

Considérant
1. Que satisfaire les besoins énergétiques mondiaux, sans effets négatifs importants sur l'environnement, est un des enjeux majeurs du développement durable ; et
2. Des avantages potentiels à collecter l'énergie solaire dans l'espace, la transmettre au moyen d'ondes électromagnétiques (micro-ondes) au sol, et ainsi alimenter le réseau électrique terrestre ; et
3. Que des études préliminaires réalisées par des spécialistes en radio-sciences ont évalué la faisabilité de Centrale solaire en orbite répondant à de tels principes, identifiant les avantages et inconvénients ;

Décide
Qu'il est du rôle de l'URSI de mettre à disposition les éléments scientifiques nécessaires et d'organiser un débat honnête et ouvert sur les enjeux techniques des Centrales solaires en orbite ; et

Recommande
Que le *Livre blanc de l'URSI sur les Centrales solaires en orbite* soit utilisé comme une référence pour entreprendre des études coordonnées à l'échelle mondiale et examiner les potentialités des Centrales solaires en orbite comme source d'énergie alternative, prenant en compte tous les aspects scientifiques, les impacts environnementaux et sociétaux, les impacts sur les autres services « radio », et la faisabilité technique et économique.

U.3 XXIXth General Assembly

The URSI Council,

Having considered the invitations for the XXIXth General Assembly which had been submitted by the URSI Member Committees in Sweden (Göteborg), Turkey (Istanbul) and the USA (Chicago, Illinois);

resolves
1. to accept the invitation of the American URSI Commitee to hold the XXIXth General Assembly in Chicago, Illinois from 7 to 16 August 2008;
2. to record its thanks to the Member Committees in Sweden and in Turkey for their invitations

U.3 XXIXth Assemblée Générale

Le Conseil de L'URSI,
Ayant examiné les invitations pour la XXIXe Assemblée générale soumises pour les comités membres de l'URSI en la Suède (Göteborg), la Turquie (Istanbul) et aux Etats-Unis (Chicago, Illinois);

Décide
1. d'accepter l'invitation du comité américain de l'URSI pour organiser la XXIXe Assemblée générale à Chicago, Illinois de 7 à 16 août 2008;
2. d'adresser aux comités membres en la Suède et en la Turquie ses remerciements pour leurs invitations.

U.4 Vote of Thanks to the Indian URSI Committee

The URSI Council,

resolves unanimously to convey to the Indian URSI Commitee its warm thanks and appreciation for the organisation of the XXVIIIth General Assembly in New Delhi.

U.4 Remerciements au Comité indien de l'URSI

Le Conseil de l'URSI,

décide à l'unanimité de transmettre au comité indien ses vifs remerciements et son appréciation pour l'organisation de la XXVIIIe Assemblée générale à New Delhi.

2004 Electromagnetics Prize Awarded

The Electromagnetics Prize, dedicated by URSI and sponsored by the Summa Foundation, was awarded in 2004 to Prof. Ludger Klinkenbusch, University of Kiel/Germany, for his solution of the problem "Scattering of a Plane Electromagnetic Wave by an Infinitesimally Thin Perfectly Conducting Quarter Plane." The bestowal of the prize – USD 10,000 and a certificate – was organized as a festive ceremony during the 2005 conference of the German URSI Member Committee in Miltenberg/ Kleinheubach in September, 2005. Prof. Karl Langenberg, President of the German Committee and a member of the prize competition panel, gave a brief introduction. He explained that the problem posed bridging the gap between Sommerfeld's famous solution of the half-plane problem, utilizing analytic functions on Riemann surfaces, and Klinkenbusch's approach to the quarter-plane problem, bringing the eigenfunctions of the elliptical cone into play.

The President of URSI, Prof. Kristian Schlegel, handed over the prize (Figure 1). Prof. Klinkenbusch then presented a tutorial overview on his solution. In principle, the eigenfunction expansion of the dyadic Green function was used to calculate the induced surface-current density on the quarter-plane, which was the source of the scattered field. However, the resulting series expansion suffered from divergence, and this problem was attacked and solved by Klinkenbusch with a tricky summation technique. This yielded numerical results for the quarter-plane diffraction coefficient from an analytical expression, as requested by the 2004 Electromagnetics Prize problem.

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Figure 1. Prof. Ludger Klinkenbusch (l) received the 2004 Electromagnetics Prize from URSI President Prof. Kristian Schlegel.

Conferences

CONFERENCE REPORT

IWSE 2005

International Workshop on Seismo Electromagnetics

Chofu, Tokyo, Japan, 15 - 17 March 2005

This IWSE was organized by The University of Electro-Communications (UEC) and its Research Station on Seismo Electromagnetics, also sponsored by URSI (International Union of Radio Science) Commission E, the Society of Atmospheric Electricity of Japan, and Institute of Electrical Engineers of Japan, and financially supported by several foundations.

The workshop was intended to provide a scientific forum on the rapidly-growing challenging science on seismo electromagnetics (electromagnetic phenomena associated with earthquakes and lithosphere-atmosphere-ionosphere coupling), and attracted about 200 participants from about 30 countries (including 80 foreign participants).

The workshop was started with two welcoming addresses ; the first one was given by Prof. A. P. Mitra (Honorary President of URSI, India), who showed a lot of interests in this new science field and showed a strong desire that India would participate in this study. The next one was given by Prof. T. Masuda, President of UEC, who expressed his interest on the hopeful future of seismo electromagnetics as the possible earthquake prediction.

44 oral papers (11 key papers and 33 contributed papers) and also 110 poster papers were presented (as the total of 143 papers). The key sessions are concerned with (1)seismo-lithospheric effect, (2)signal processing of seismogenic phenomena, (3)seismo-atmospheric and -ionospheric phenomena and lithosphere-atmosphere-ionosphere coupling, and (4)spaceborne observations of seismogenic phenomena.

In these reviews the authors have presented some brief review on each topic and then they have presented their own latest results. The physical cause of pre-seismic electromagnetic emissions has been discussed in term of electronic charge carries (known as positive holes) in typical crustal rocks, and this concept has been applied to the Chi-chi earthquake in Taiwan. The ULF activity jointly done by RIKEN and NASDA frontier groups has been reviewed, with an emphasis on the use of sophisticated signal processing for seismogenic ULF emissions. Also, new observations on ULF emissions have been presented on the basis of data observed at Kamchatka.

The importance of sophisticated signal processing has been suggested in order to find out any seismogenic emissions. Then, seismo-atmospheric perturbations have been studied with the use of over-horizon VHF signal, and also the corresponing seismo-ionospheric perturbations have been observed by different methods (satellite observations, subionospheric VLF/LF propagation, TEC (Total electron contents) etc.) .

A few possible mechanisms of ionospheric perturbations have been suggested ; (1) Effect of DC electric field and (2) atmospheric gravity waves. In the 4th key session, we were extremely excited with looking at the first observational results from the two satellite projects (French DEMETER and American QuakeSat), in which very promising observational results have been presented in possible future collaboration with the ground-based observation for the study of lithosphere-atmosphere-ionosphere coupling mechanism.

Also, there have been presented interesting results on remote sensing from satellites of Earth's surface by passive and active soundings. Surface temperature is found to increase by a few degrees near the active fault of the future earthquake about one week before the earthquake.

A lot of new observational and theoretical works have been presented in the oral and poster sessions, especially on the DC seismic electric signals, ULF emissions, ELF/VLF emissions and electromagnetic emissions in higher frequency even up to microwave. Again, sophisticated signal processing including natural time-domain method, fractal (mono- and multi-fractal) analysis etc, have been proposed and applied to the analysis for DC and ULF electromagnetic field changes. Japanese contribution was very noticeable in the subject of over-horizon VHF signal reception associated with earthquakes. A new discovery has been presented on the anomalous behavior of Schumann resonances observed in Japan, in possible association with the Chi-chi erarthquake in Taiwan, and it attracted a lot of attention from the participants.

Seismo-atmospheric and –ionospheric perturbations have been extensively studied. Ionospheric perturbations have been studied by means of different methods including satellite observation, bottomside sounding, GPS method and also our subionospheric VLF/LF propagation.

A special poster session on the precursory electromagnetic phenomena for the recent Japanese earthquakes (Tokachi-oki, Kii peninsula, Mid Niigata Prefecture earthquakes etc.) has been organized, being consisting of 11 posters. Some new directions appeared; (1) the use of direction finding to locate the source, (2) a new approach to detect anomalous geoelectrical areas by monitoring the malfunction of radio telemetry network, (3) ELF Schumann resonances as a probe of earthquakes etc. These poster papers attracted a lot of attention of the participants and some mass media.

The details of the workshop can be found in the Abstracts and in the website, http://www.iwse.ee.uec.ac.jp . You will be able to enjoy the friendly atmosphere of the workshop and also the high-quality scientific papers presented there.

Two special issues are planned to collect the papers not only presented in the IWSE, but also those which could not unfortunately be presented there. One is a special issue in IEEJ entitled "Recent Progress in Seismo Electromagnetics" (Guest Editor, M. Hayakawa), and will appear in April, 2006. Another will be a special issue in Phys. Chem. Earth (with the guest editors ; M. Hayakawa, O. A. Molchanov, S. Pulinets and M. Parrot) . You will be able to understand the recent progress in the field of seismo-electromagnetics.

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URSI Commission F Symposium on Microwave Remote Sensing of the Earth, Oceans, Ice, and Atmosphere

Barza, d'Ispra, Italy, 20 - 21 April 2005

Introduction

The URSI 2005 Commission F Symposium was organized by the Sensors, Radar Technologies, and Cybersecurity Unit, Institute for the Protection and Security of the Citizen, Directorate General Joint Research Centre of the European Commission. The invitation to organize the Symposium came from the present Vice-Chair: of the Commission F - Wave Propagation and Remote Sensing, Prof. Martti Hallikainen (Helsinki University of Technology, Finland). The selected venue of the URSI-F 2005 Symposium was Conference Centre Casa Don Guanella, in Barza d'Ispra (Varese, Italy). Barza d'Ispra is located close to the Lake Maggiore (Northern Italy).

The meeting was attended by a total of 62 scientists. Even if most participants were European, there were some coming from non-EU Countries such as Russia, Turkey, USA, Japan, and Australia. The program included 40 oral presentations and 8 posters, which were on display during the two days of the meeting.

The motivation to organise the meeting was twofold:

- to provide a premier forum for the scientific community to discuss the latest results and to identify developing trends in the field of wave propagation and remote sensing both with active and passive systems.
- to deliver a number of keynote presentations by leading researchers, which are intended to review the current "state of the art" in the field of microwave remote sensing.

Logistics Issues

On the first day in the morning all participants completed the registration procedure and got a copy of the booklet of abstracts and the symposium program. We thank Marta Garotta, Valeria Anfossi, and Gianluigi Ruzzante for following this up. Since the location of the meeting was not easily reachable by public transport, it was necessary to organize a significant number of transfers to/from the airports and train station in Milan. Both Valeria Anfossi and Marta Garotta very professionally followed this up (thanks again to them!).

Summary of the Sessions

All sessions of the symposium were well attended and raised significant interest among the audience.

The program was organized in 8 sessions, namely:

1. SAR Interferometry
   This session started with a keynote presentation by Prof. Claudio Prati (POLIMI, Italy) on the permanent scatterers (PS) technique. There were a total of four presentations dealing with the issue of the monitoring of landslides using space-borne radar imagery. The rest of the session covered various issues of interest within the SAR interferometry community, such as the use of multiple-baselines, multiple frequency bands, the retrieval of biophysical parameters, and the retrieval of digital elevation models.

2. Ernst Lüneburg Memorial Session.
This session was kindly introduced by Prof. Madhu Chandra, who was a friend and former colleague of Dr. Lüneburg. This session included talks by some of his most important collaborators: Prof. Boerner (Univ of Chicago, USA), who was behind the organization of this memorial session, Prof. Czy (Poland), Dr. Serbest who presented some personal and technical reflections on his long collaboration with Dr. Lüneburg (TUBITAK, Turkey), Dr. Danklmayer (DLR, Germany), and Dr. Lopez (Univ. of Rennes, France)..
3. Advanced Topics in SAR.
This session covered a series of interesting new developments in the field of SAR techniques and applications. The session included presentations on new texture analysis and segmentation techniques, formation of three-dimensional radar images, tsunami damage assessment using space-borne radar imagery, flood detection in Finland using SAR, retrieval of soil moisture using ENVISAT SAR images, monitoring of vessel illicit discharges, and monitoring of vegetation using SAR imagery.
4. Early Warning of Earthquakes and Tsunami.
This session included four keynote presentations on the state of the art in the field of early warning of earthquakes and tsunami. Prof. Sgrigna (Univ. of Rome, Italy) presented the present status of his investigations on pre-earthquake phenomena using space missions. Prof. Sarlis (Univ. of Athens, Greece) introduced his work on the analysis of seismic electric signals and the subsequent seismicity in the natural time domain. Dr. Martín-Neira (ESA, The Netherlands) presented the potential use of a constellation of global navigation satellite receivers to give an early warning of tsunami. This technique was originally designed for sea altimetry applications. The session ended with the keynote speech by Prof. Boerner on the recent advances in the field of early warning of earthquakes made in Taiwan.
5. Ground-Based Systems.
This session included presentations on various ground-based radar systems presently in use to monitor landslides, mines, volcanoes, and imaging of trees. Two companies offering monitoring services on a commercial basis presented some example cases where ground-based radars have proven to be very successful.
6. SMOS Session.
This session included a keynote speech by Dr. Martín-Neira presenting the present development state of the Soil Moisture and Ocean Salinity (SMOS) Satellite. Then there were two talks on calibration campaigns with polarimetric radiometers in Spain, JRC-Ispra, and the Antarctica, in the frame of the SMOS mission.
7. Monitoring of the Snow Cover.
This session included three talks on various techniques to retrieve snow parameters based on active radar systems. The JRC presented the results of a recent field campaign with its ground-based SAR instrument (LISA) in the avalanche test site of Sion (Switzerland).
8. Radar Polarimetry.
This session was organized in collaboration with the chairman (Prof. Chandra) of the European Training and Research Network financed by the EC Directorate General Research AMPER (Application of Multiparameter Polarimetry in Environmental Remote Sensing). This session included a series of presentations on radar polarimetry given by the AMPER pre- and post-doctoral fellows. There were also two presentations by Prof. Migliaccio (Univ. of Naples, Italy) on the use of polarimetry for a more effective detection of oil spills and a better retrieval of the windfield.
9. Posters Exhibition.
A total of five posters were exhibited during the symposium. The covered topics were a new radar missions for the remote sensing of the sea, measurements of the Microwave attenuation spectra of forests, an improved clutter suppression in random noise radar, 3-D SAR in curved paths for remote sensing applications, and a preliminary statistical analysis of textural features in RADARSAT-1 images of an urban area.

Symposium Website

All submitted papers as of today and the full programme of the meeting are available in the internet at this address: http://ursi-f-2005.jrc.it

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Dr. Joaquim Fortuny (right; TPC Chair) and Prof. Martti Hallikainen (left; Commission F Chair) during the Symposium

ETTC '05
European Test and Telemetry Conference
Toulouse, France, 7 - 9 June 2005

Flight test professionals meet regularly twice a year, once in USA once in Europe. The meetings in Europe are organized alternatively in France (Toulouse, 2005 June 7-9) and in Germany (Garmisch-Partenkirchen, 2006 May 29-June 1st). For the last eight years the International Consortium for Telemetry Spectrum (ICTS Chair, Steve Lyons) has been associated with the Conference working on the access conditions to the frequency spectrum (Subject which is on the agenda of WRC'07 under item 1.5).

Rare are the Conferences where scientists, manufacturers of instruments and Flight Test Centres are closely associated as in the case for ETTC. The organisation of the Conference is certainly more complex, but participants fully benefit from the fruitful discussions, particularly in the stands on which they can debate of the pros and cons of real pieces of equipment.

The Conference ended with a "round table" on the following theme: "Questions raised by the integration of UAVs in conventional air space : impact on frequency needs depending on the mission variance".

From the large variety of subjects three of them emerged : EMC, antennas, UAVs.

EMC

One can easily imagine the importance of EMC in flight test instrumentation. Christian Carel has to be thanked for his excellent survey on the present status of the subject and the outline of its evolution. The knowledge management in this domain was also presented (C.Girard & al.); it showed how difficult it was and pointed to the importance of long experience to solve EMC problems within very complex configurations.

ANTENNAS

The importance of this domain has been stressed again and again, in particular the antenna-structures interactions. The measurements of antenna patterns of full size air vehicles was one of the most interesting themes (T.Fritzel & al.).

UAV

The debate concentrated on two main areas, Flight Test Centres and the integration of UAVs in civil aviation air space. The need of additional frequency bands was underlined by all. However, operating procedures of UAVs are far from being settled.
Scientists will still have to wait for another few years before using them.

The Conference assembled some 200 participants (From countries of the three ITU Regions, although one wishes more participants from the Region 3). They benefited from good weather conditions to visit some technical installations around Toulouse and have a cheerful banquet dinner in Château de Luzac .

The ETTC'05 was co-organised by the SEE (site : www.see.asso.fr) and the AAAF(site : www.aaaf.asso.fr). Our sincerest thanks go to all organisers (Organising Committee Chair, Florent Christophe) and the Programme Committee (Y.Remillieux) for offering the opportunity for such fruitful exchanges.

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The Participants in the ETTC'05 having discussions during one of the breaks

EMC 2005
The VIth International Symposium on Electromagnetic Compatibility and Electromagnetic Ecology

St - Petersburg, Russia, 21 - 24 June 2005

The VIth International Symposium on Electromagnetic Compatibility and Electromagnetic Ecology (EMC-2005) was held from 21 to 24 June 2005 at the St - Peterburg State Electrotechnical University "LETI", Russia. The meeting was attended by 152 participants (103 Russian and 49 foreign scientists) from 21 countries.

As in the preceeding years, the Symposium was sponsored by the Institute of Electrical and Electronics Engineers (IEEE), the IEEE Electromagnetic Compatibility Society (EMS-society), the International Union of Radio Science (URSI) and the Research-and-production Enterprise "Proryv" (official Partner of the Symposium) and has been jointly organized by the St - Petersburg State University "LETI", the St - Petersburg Scientific and Technical Society of Radio Engineering, Electronics and Communication (named after A.S.Popov), the Leningrad Radio Research and Development Institute and Discone-Centre Ltd., in Cooperation with the Federal Agency for Education, the Ministry of Information Technologies and Communications of the Russian Federation, the Russian Academy of Sciences, the Users Association of Natural Radio-Frequency, the Resource-National Radioassociation, the St-Petersburg State Polytechnical University, the St- Petersburg State University of Telecommunications (named after M.A. Bonch-Bruevich), the St-Petersburg State Maritime Technical University, the Moscow Technical University of Communication and Information Science, the Radiofrequency Centre of the North-West Federal District, the Research Institute of Radio, the Research Institute of Pulse Engineering, the Research Test Centre for EMC, the Research-and-production Enterprise "Proryv", the Kedah Electronics Engineering, the IEEE Russian (North-West) Section, the Russian Branch of IEEE "Engineering-management and the Elemcom Ltd.

Prof. M. Ianoz acted as Symposium Vice-President. The Technical Program Committee was chaired by Prof. N.Korovkin from the St-Petersburg State Polytechnical University and the Scientific Secretary of the Symposium consisted of Dr. S. Shostakovich, General Director of Discone-Centre Ltd., Dr. P. Asovich and Dr. V. Gutin.

A number of international and national professional organizations (e.g. IEEE, EMC-society, and URSI) cooperated at the EMC 2005 meeting. As in the past URSI Commissions E sponsored 15 students from Russia and foreign countries.

A total of 174 carefully selected technical papers were presented in 10 sessions devoted to: EMC of Electrical Power Equipment, Spectrum Management and Monitoring, Biological Effects of electromagnetic (EM) Field, Natural EM Radiations, Sources and Influence, Antennas and Propagation, EMC Related to PCB's and Electronic Components, EMC Monitoring Measurements, Certification, Test Equipment, Electromagnetic Interaction and Shielding, Radio Electronic Equipment design with regard to EMC, EMC in Radio Communication Systems, and Workshop "Shipbord EMC". The full text of the presentations has been made available in the symposium proceedings and on a CD-ROM.

The emphasis of the Symposium was on the field of EMC Monitoring, active diagnostics, measurements, certification and biological effects of Electromagnetic Fields, an estimation of the influence of external Electromagnetic Fields on the measuring accuracy, a design of measuring devices and an immunity test simulationfor conductive interferences.

The EMC Symposium was introduced by three lectures, devoted to the latest achievements of science and engineering. Especially, the lectures from Prof. M.Ianoz and Prof. M.Korovkin, "Progress in the PLC development during the years 2003-2004" and from Prof. Yu.G.Grigoryev "Electromagnetic fields of mobile radio communication and hazard estimation for the Population" were a great success.

As usual, the Technical Exhibition has significantly contributed to the success of the VI-th International Symposium on Electromagnetic Compatibility and Electromagnetic Ecology (EMC-2005) by demonstrating the fast conversion of theoretical knowledge into state-of-the art hardware and software.

The traditional inquiry returned some very interesting suggestions for the next EMC-2007, which is planned for June, 2007 and will be held in St-Petersburg. The call for papers of the VII-th International Symposium on Electromagnetic Compatibility and Electromagnetic Ecology and Technical Exhibition on EMC is scheduled for March, 2007.

In the Autumn of 2006 St-Peterburg State Electrotechnical University "LETI" celebrates his 120th anniversary ! The EMC - 2007 will be one of the several events under the umbrella of this anniversary.

Professor V. Larkina
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IRI 2005 Workshop
New Satellite and Ground Data for IRI and Comparison with Regional Models

Roquetes, Spain, 27 June - 1 July 2005

As part of its centennial celebrations, the Ebro Observatory in Roquetes, Spain, hosted the 2005 International Reference Ionosphere (IRI) Workshop. Workshop sessions, held at the Observatory and the Auditory Felip Pedrell in neighboring Tortosa from June 27 to July 1, covered the typical IRI topics: F-region Modeling, Bottomside Parameters and Drifts, Topside Ionosphere, IRI Applications, Temperature and Composition, Ionospheric Variability, Lower Ionosphere, Total Electron Content, and New Inputs for IRI. The agenda included 66 presentations by 48 scientists from 18 countries illustrating the global reach and importance of the IRI activities. Ground and space data sources were evenly represented including data from many ionosondes, and from most incoherent scatter radars, and from the satellites Akebono, CHAMP, DMSP, GPS, Hinotori, IK-19, IK-24, IMAGE, ISIS, JASON, Ohzora, ROCSAT, TIMED, TIROS/NOAA, and TOPEX, and from several rocket flights. The meeting benefited from the excellent local support under the leadership of Dr. David Altadill. The Observatory team not only patiently shepherded the international group of scientists during the session periods, but also arranged an evening walking tour of Tortosa and a conference excursion to the beautiful Tortosa-Beseit Natural Park and the Picasso Center in Orta de Sant Joan. Opening and closing ceremonies were attended by local and regional politicians who pledged their support for the Observatory and acknowledged the importance of holding this international science meeting in their town and region. Financial support was provided by the following organizations: Committee on Space Research (COSPAR), International Union of Radio Science (URSI), European Office of Aerospace Research and Development (EOARD) of the US Air Force Office of Scientific Research, Consejo Superior de Investigaciones Cientificas (CSIC), Ministerio de Educación y Ciencia (MEC), Agència de Gestió d'Ajuts Universitaris i de Recerca (AGAUR) and by the Observatori de l'Ebre. Also the Mayor's Offices of the Towns of Roquetes and Tortosa, the Council of the Lower Ebro Area, La Caixa, the Ramon Llull University and Diario ABC supported this event.

Electron Density :Topside, Plasmasphere, and TEC

The new version of IRI, due to be released later this year, will include two options for the topside electron density: (1) the correction term for the current IRI model as proposed by Bilitza (USA) and (2) the newest version of the NeQuick model as presented by Coisson (Italy).

Reinisch (USA) explained his new approach of representing the topside and plasmasphere electron densities by a Chapman profile with continuously varying scale-height using the developing UML plasmasphere model that is based on IMAGE/RPI and ISIS measurements. Alternatively, Pulinets (Mexico) and Depuev (Russia) are proposing the use of an Epstein function with variable scale-height and have successfully applied this approach to their IK-19 topside sounder data. An important aspect of their model is the inclusion of persistent longitudinal features. Uemoto (Japan) presented Ohzora and Akebono topside sounder data as a possible source for improvements of the IRI topside profile. Plasmaspheric extensions of IRI were discussed by Coisson (Italy) and by Gulyaeva (Russia) using the Global Core Plasma Model (GCPM) developed by Gallagher et al. (USA). Garner (USA) found that binned DMSP data follow a lognormal distribution and he studied global and solar activity variations of the distribution parameters.

There were quite a number of presentations of TEC-related studies including: (1) Comparisons of GPS TEC with ionosonde ITEC measurements (McKinnell, South Africa; Mosert, Argentina), (2) Comparisons of TEC measurements with IRI predictions (Bhuyan, India; F. Arikan, Turkey; Moeketsi, South Africa; Opperman, South Africa). (3) Ionospheric tomography techniques and their utilization of IRI (O. Arikan, Turkey; Bhuyan, India; Opperman, South Africa), (4) Ionospheric data obtained by different dual-frequency space techniques and their use for improvements of IRI (Bilitza, USA), (5) An assessment of 2nd order ionospheric effects on GPS measurements (Hernandez-Pajares, Spain), (6) Using a wavelet/spline approach as an initial step of a multi-resolution representation of TEC (Schmidt, Germany) (6) A method for deducing foF2 from GPS-TEC (Krankowski, Poland).

Electron Density : F-peak and below

The main new input for the next version of IRI will be the spread-F occurrence model for the South-American sector that was developed by Abdu (Brazil) based on ionosonde data. Efforts are under way to develop a quantitative description of ionospheric variability in terms of quartiles and deciles for inclusion in IRI (Mosert, Argentina; Altadill, Spain).

In IRI the height of the F2 peak is computed from the M(3000)F2 factor that is regularly measured by ionosondes. A study by M. Zhang (China) showed that the shortcomings of IRI in representing the sunrise and post-sunset peaks in hmF2 are a result of the shortcomings of the CCIR model used for M(3000)F2. Good agreement is obtained when using the ionosonde-measured M(3000)F2. McKinnell (South Africa) reported about her effort in developing a neural network (NN) model for M(3000)F2, which could eventually replace the CCIR model and its shortcomings. The quality of IRI predictions during ionospheric storms was evaluated with a variety of ionosonde data (Mosert, Argentina; Araujo-Pradere, USA; Miro, Italy). Peronne (Italy) presented a storm-time modeling approach based on a time-weighted magnetic accumulation index. A validation of TIMED/GUVI nighttime electron density profiles with worldwide ionosonde data was presented by DeMajistre (USA). Good agreement was found for most stations making the GUVI profiles a promising new data source for IRI nighttime improvements.

The diurnal, seasonal, and solar cycle variations of bottomside profile parameters were studied by Mosert (Argentina) and by Blanch (Spain) based on ionosonde data with the goal of improving the current representation in IRI. Altadill (Spain) is proposing analytical functions to replace the current tabular form in which these parameters are provided in IRI. He also used such functions to represent vertical drift measurements from the Ebro digisonde.

E-region modeling is focusing on the auroral region and a representation of the enhanced foE due to particle precipitation (Fuller-Rowell, USA, NOAA/Tiros data; Mertens, USA; TIMED/SABER data). McKinnell (South Africa) is proposing a NN approach to modeling the density distribution in the auroral zone lower ionosphere.

IRI currently includes Friedrich's (Austria) FIRI model as a separate option for the D-region electron density only. But the model is forced to agree with the IRI E-peak. This results in E-region values that are quite different from the original data-based FIRI predictions. It was therefore decided to decouple the FIRI model option from the E-peak constraint and make it accessible all the way to 140 km.

Plasma Temperatures, Ion Composition, and Ion Drift

The next version of IRI will include several new inputs: (1) a model for the plasmaspheric electron temperature based on Akebono data (Kutiev, Bulgaria and Oyama, Japan), (2) the TTS model for the topside ion composition based on IK-24 and AE-C,-E data (Triskova and Truhlik, Czech Republic), (3) a model for the storm-time vertical ion drift (Scherliess and Fejer, USA).

Su (Taiwan) presented new models deduced from ROCSAT satellite data (high solar activity) describing the topside ion density, the distribution of density irregularity, the ion temperature, and the equatorial vertical ion drift. Empirical models for parameters from 7 incoherent scatter radars have been develop by S. Zhang (USA) in conjunction with the radar groups. This will be a valuable evaluation tool for the IRI model performance at the radar locations. Kutiev (Bulgaria) has combined his model for the topside ion transition height with his topside scale-height model to provide a topside profiler for ionosondes. Bilitza (USA) and Truhlik (Czech Republic) used a large data base of satellite in-situ measurements to investigate the altitudinal, latitudinal, and seasonal differences in the solar cycle variation of electron temperatures and densities and found good agreement when comparing the observed trends with those predicted by the FLIP model. They also tested various solar indices and found best results with F10.7 and PF10.7=(F10.7+F10.7A)/2 where F10.7A is the 81-day average. The IRI Te model currently does not include solar cycle variations. Other temperature features not currently included in the IRI model were also pointed out. Oyama (Japan) reminded participants that rocket observations of large differences between electron temperature and neutral temperature around 100 km are not yet explained and are not included in IRI. Watanabe (Japan) using CHAMP observations finds high electron densities around 70° latitudes at noon and enhanced thermospheric mass density and high electron temperature in the cusp region (75°-80°). The shortcomings of the IRI ion temperature and ion composition model in representing some characteristic longitudinal and diurnal features were noted by Chao (Taiwan) in comparisons of IRI with ROCSAT data.

Meetings, Publications, New Member

Selected papers from the 2003 IRI Workshop in Grahamstown, South Africa were published as Number 9 of Volume 34 of Advances in Space Research (ASR) including 35 contributions and a dedication and paper in honor of Prof. Karl Rawer's 90th birthday. There was also a special session during the German National URSI meeting (Kleinheubacher Tagung) celebrating Karl Rawer and his contribution to the IRI effort. The papers from that session were published as the 2nd Volume of Advances in Radioscience (Kleinheubacher Berichte 2003). The reviewing process for the presentation from the 2004 IRI session during the COSPAR General Assembly in Paris, France is nearing completion and the dedicated ASR issue will be coming out later this year.

The next IRI meeting will be held during the COSPAR General Assembly in Beijing, China (16-23 July, 2006) on the topic of "Solar Cycle Variations of Ionospheric Parameters". On behalf of her Argentine colleagues M. Mosert invited the IRI team to consider holding a special IRI Workshop in Buenos Aires, Argentina in late 2006 recommending a TEC/GPS-related IRI meeting topic. Her proposal was received favorably and she will explore the financial and logistics issues connected to such a meeting. Buresova (Czech Republic) provided the participants with more information about the Institute of Atmospheric Physics in Prague, the venue for the 2007 IRI workshop. Possible dates were discussed including a coupling to the IUGG meeting in Perugia, Italy, from July 2 to 13, 2007.

Prof. C.K. Chao from the Institute of Space Science of the National Central University in Chang-Li, Taiwan was elected as new member to the IRI Working Group.

Dieter Bilitza
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International Symposium on Coherence and Electromagnetic Fields in Biological Systems (CEFBIOS 2005)

Prague, Czech Republic, 1 - 4 July 2005

The symposium organized as the Fröhlich centenary symposium was a tribute to Professor H. Fröhlich, the outstanding scientific personality, one of the great physicists of the 20th century. He formulated many concepts of modern theoretical physics. We have to mention introduction of the methods of quantum field theory into Solid State Physics (in particular in the theory of dielectrics included in the book "Theory of Dielectrics"), fundamental contribution to the theory of superconductivity based on formulation of a hitherto unrecognized aspect of the electron-phonon interaction, and the meson theory of nuclear forces. He introduced a concept of coherence into biology. From the point of view of physics, living systems are highly non-linear open dissipative systems with remarkable dielectric properties, which are held far from thermal equilibrium by their metabolic activity. The lowest frequency mode of a longitudinal electric polarization field becomes strongly excited creating macroscopic coherent excitations, which are stabilised through elastic deformations. Polarization waves can generate electromagnetic fields in biological structures. Dr. G.J. Hyland paid tribute to H. Fröhlich and presented the centenary lecture in Carolinum, the ancient ceremonial building of the Charles University.

The highlights of the symposium were the following: coherence and electromagnetism in biological systems, interaction of biological systems with external electromagnetic fields, and medical applications of electromagnetic fields.

The fundamental quantum mechanical problems of the macroscopic living and non-living, superposition of aggregates, and coherence (H.-P. Dürr) and description of a living system in terms of quantum electrodynamics by a density matrix of individual wave functions (E. Del Giudice) were presented. Endogenous electromagnetic field has an essential role in living systems (A.R. Liboff). Microtubules in eucaryotic cells are electrically polar polymers with extraordinary elastic deformability and with high energy supply and their structures satisfy conditions for excitation of the Fröhlich's coherent states and generation of endogenous electromagnetic field (J. Pokorný et al.). Effect of different modalities of energy supply to the Fröhlich modes on behavior of the coherent system was analysed (F. Šrobár). Properties of microtubules can be understood by observation of movement of microtubules in constant and in alternating electric fields (E. Unger et al.). Unidirectional propagation of the kink excitation along the microtubule can explain dynamic instability phenomenon and elucidate the unidirectional transport mediated by motor proteins (M.V. Satariæ). A system made of an ensemble of yeast cells can be a good prototype of the concept of coherence (M. Milani et al.). Solitons in protein á helix can generate endogenous electromagnetic field of characteristic frequencies leading to synchronization of charge transport processes (L.S. Brizhik, A.A. Eremko).

Model of neuroactivity can be provided by the field theory from condensed matter physics (G. Vitiello). Perturbations generated by the C-termini interactions with counter-ions surrounding a MAP2 (microtubule associated protein 2) may propagate in brain over distances greater than those between adjacent microtubules (A. Priel). Primary role in brain dynamic activity is played by coupling between elementary plasma domains (J.R. Zon). Some neurobehavioural changes caused by Mn penetrating the blood-brain barrier in rats after exposure to the magnetic field was observed (M. Vojtíšek et al.).

Magnetic field 0.05 mT/50 Hz can alter the cell mediated immunity of T lymphocytes in humans (A. Jandová et al.). Magnetic fields 50 Hz up to 10 mT affect the growth and metabolic activity of different strains of bacteria (L. Strašák et al.). External magnetic field can influence biological processes through cyclotron resonance of ions (C. Vincze et al.). Alternative form of magnetic transduction involving electric field ionic cyclotron resonance may occur within the avian optic tectum which may serve as the magnetoreceptors (K.A. Jenrow, A.R Liboff). Theory of plasma state of ionic matter shows that small electric potential differences can reveal the state of life and measurement confirms the predictions (I. Jerman et al.). Delayed luminescence generated in photosystem II with typical hyperbolic decay in time and with more or less pronounced peak allows simple and fast method for assessment of influence of toxic materials on plants (A.

Zrimec et. al). Overview of experimental results of non-thermal biological effect of microwaves based on present state of the art shows a necessity of minimizing their adverse effects (I. Belyaev).

Effects of bioelectrochemical methods for cancer therapy causing electrolytic cell destruction, electroporation of membranes, and changes of metabolism can be enhanced by hyperthermia, by photodynamic action, and by cytotoxic agents (H. Berg). Medical application of microwaves must have adequate technical basis (J. Vrba). First experimental results on microwave imaging (microwave tomography) shows possible application in medicine (M. Persson et al.). Microwave pulses from MRI scanners induce acoustic pressure waves in head (J.C. Lin and Z. Wang). Experimental visualization of light piping channels in humans was presented (F.-A. Popp et al.). Measurement of yeast cells at 42 GHz and power level 10^{-17} W does not reveal statistically significant exited vibration modes (F. Jelínek et al.).

Two “Round table discussions” were included into the program of the Symposium: “What effects have electromagnetic fields on water?” and “Role of physical forces in organization of living matter”.

What effects have electromagnetic fields on water:

The main physical contributions were made by the V.I. Lobyshev and E. Del Giudice. The symmetry, multiplicity and cooperativity of hydrogen bonds determine the collective properties of water distinguishing it from simpler fluids. Changes of physico-chemical properties of water and aqueous solutions under the action of weak fields of electromagnetic, as well as of the acoustical, and vibrational nature are registered. For understanding of water properties optical characteristics in UV, visible, and IR ranges, electric and thermodynamic characteristics are important. Luminescence in UV and in visible range shows that the structural equilibrium in water is not stable in general. Physical measurements suggest the existence of various supramolecular hierarchic structures in liquid water (the positive and the negative charges—„binding sites“—of a water molecule form corners of a nearly regular tetrahedron). Water at each moment of time constitutes a structure containing ordered clusters and disordered regions like a crystal with defects. The principal step is made from well-known crystalline structures to parametric structures of generalized crystallography. At room temperature and pressure liquid water is a mixture of coherent and non coherent fractions. Measurements of the effects of water treated by the electromagnetic field on properties of biological systems—on bacteria *Escherichia coli* and on cress seeds—were presented too (R. Krašovec et al, R. Ružiè et. al.).

Role of physical forces in organization of living matter:

Contributions of E. Del Giudice, of G.J. Hyland, of F.-A. Popp, of V.N. Binhi, of L.S. Brizhik of A.R. Liboff, of M.V. Satariæ, and of J. Zon pointed out the fundamental physical concepts in organization. Organization has to be understood as organization of morphological structures, of spacio-temporal chains of chemical reactions, and of generation of endogenous electromagnetic fields. Large number of particles coupled to the electromagnetic field can form coherent domains. Macroscopic wave functions can describe the biologically relevant states. Non linear soliton dymanics can participate in transfer of charges and energy. Water bound in biomolecules have significant role in molecular dynamics. Electromagnetic field can participate in transport of charges and dielectric particles (molecules) and form lines of force structures for positioning of material. All processes in biological systems have a deterministic (or coherent) and a random (thermal) component. Generally, organization of biological systems cannot be understood without taking into account endogenous electromagnetic fields.

The symposium was devoted to the vigorously developing area of human knowledge about living matter. About one hundred scientists from 20 countries participated in the Symposium, presented papers and took part in discussions about fundamental physical concepts of life. The Symposium took place in Prague, the Czech Republic, from July 1 to July 4, 2005 and was organized by the Institute of Radio Engineering and Electronics of the Academy of Sciences of the Czech Republic, by the Ist Medical Faculty of the Charles University, by the Faculty of Electrical Engineering of the Czech Technical University in Prague, by the National Institute of Public Health of the Ministry of Health Care of the Czech Republic, under the aegis of Professor Š. Svaèina, dean of the Ist Medical faculty and of Dr. V. Matìjec, director of the Institute of Radio Engineering and Electronics, under auspices of the International Comission K of URSI, and of the National URSI Committee of the Czech Republic, and of the Czechoslovak Section of IEEE. Honorary organizers were Università degli Studi di Milano, Bicocca—Italy, Università degli studi di Salerno—Italy, Department of Biophysics of the Faculty of Mathematics, Physics and Informatics of the Comenius University in Bratislava—Slovak Republic, and the Catholic University in Lublin—Poland.

Invited papers will be published in the journal “Electromagnetic Biology and Medicine”—24(3)2005.

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CONFERENCE ANNOUNCEMENTS

36TH COSPAR SCIENTIFIC ASSEMBLY AND ASSOCIATED EVENTS

Beijing, China, 16 - 23 July 2006

Scientific Program Chair

Prof. Ronglan Xu, Center for Space Science and Applied Research (CSSAR), Beijing, China

Topics

Approximately 80 meetings covering the fields of COSPAR Scientific Commissions (SC) and Panels:

- SC A: The Earth's Surface, Meteorology and Climate
- SC B: The Earth-Moon System, Planets, and Small Bodies of the Solar System
- SC C: The Upper Atmospheres of the Earth and Planets Including Reference Atmospheres
- SC D: Space Plasmas in the Solar System, Including Planetary Magnetospheres
- SC E: Research in Astrophysics from Space
- SC F: Life Sciences as Related to Space
- SC G: Materials Sciences in Space
- SC H: Fundamental Physics in Space
- Panel on Satellite Dynamics (PSD)
- Panel on Scientific Ballooning (PSB)
- Panel on Potentially Environmentally Detrimental Activities in Space (PEDAS)
- Panel on Radiation Belt Environment Modelling (PRBEM)
- Panel on Space Weather (PSW)
- Panel on Planetary Protection (PPP)
- Panel on Capacity Building (PCB)
- The Public Understanding of Space Science
- Space Science Education and Outreach

The papers will be published in: *Advances in Space Research.*

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http://www.copernicus.org/COSPAR/COSPAR.html

Abstract Deadline: 17 February 2006

10TH INTERNATIONAL CONFERENCE ON IONOSPHERIC RADIO SYSTEMS AND TECHNIQUES

London, United Kingdom, 18 - 21 July 2006

The call for papers for the forthcoming IEE Ionospheric Radio Systems and Techniques conference is now available from http://conferences.iee.org/IRST2006/.

The conference will take place from 18-21 July 2006 in London and is organised by the IEE Communications Networks & Services Professional Network.

Historically this conference has concentrated on HF systems and propagation but this year the scope has been widened considerably to include other ionospheric systems and propagation issues.The scope of the meeting is summarised below.

Organising Committee

P.R. Green, University of Manchester, Chairman
P. Arthur, QinetiQ
Prof. L.W. Barclay, Barclay Associates Ltd
Prof. P.S. Cannon, University of Bath
C.R. Harding, QinetiQ
Prof. B. Honary, SECAMS, University of Lancaster
M Warrington, University of Leicester

Scope

- Historical perspectives
- Ionospheric and trans-ionospheric propagation effects
- Ionospheric and trans-ionospheric radio and radar systems
- Transmitters, receivers and antennas
- Spectrum management
- Future requirements
- Lessons learnt

Contact

IRST 2006 Organiser
The IEE, Event Services
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Tel: +44 (0) 1438 765647
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Email: eventsa2@iee.org.uk

ISAPE 2006

Guilin, China, 26 - 29 October 2006

The Seventh International Symposium on Antennas, Propagation, and Electromagnetic Theory (ISAPE) will be held October 26-29, 2006, in Guilin, often referred to as one of the most beautiful cities in China. This is a continuation of the series of meetings started in 2000, which came out of the combination of the former International Symposium on Antennas and Electromagnetic Theory (ISAE) and the International Symposium on Radiowave Propagation (ISRP), both sponsored by the Chinese Institute of Electronics (CIE). The ISAPE2006 is sponsored by the CIE; is co-sponsored by the IEEE Beijing Section, the IEE Beijing Branch, and the China Committee for URSI; and is technically co-sponsored by the IEEE Antennas and Propagation Society, the IEEE Geoscience and Remote Sensing Society (GRSS), and the Institute of Electronics, Information and Communication Engineers, Japan.

Radio scientists and electrical engineers from all countries are invited to submit papers and to participate in the ISAPE2006. The working language for the symposium is English. Papers are solicited in more than 45 specific topical areas, under the broad topics of Antennas, Propagation, EM Theory, and Applications in these areas. The full list of topics is available on the symposium Web site at http://www.cie-china.org/isape2006/. The deadline for submission of camera-ready papers is July 30, 2006. Submission instructions and a paper template are available on the Web site; papers can be e-mailed to Donglin Su at *sdl@buaa.edu.cn*

The General Co-Chairs of the meeting are Yiping Wang (China) and W. Ross Stone (USA). The Chair of the Program Committee is Donglin Su. Direct inquiries related to local organization matters and visas to *Mr. Dayong Liu,* e-*mail: cieint@public3.bta.net.cn*.

URSI CONFERENCE CALENDAR

An up-to-date version of this Conference Calendar, with links to various conference web sites can be found at www.ursi.org/ Calendar of supported meetings

May 2006

ISSTT 2006 - International Symposium on Space Technologies
Paris, France, 10-12 May 2006
Contact : Chantal Levivier, ISSTT 2006, Observatoire de Paris, 61, avenue de ‘l Observatoire, F-75 014 Paris, France, E-mail : isstt2006@mesiog.obspm.fr , Web : http://wwwusr.obspm.fr/gemo/ISSTT06/Accueil/PageAccueil.html

EUSAR 2006 - 6th European Conference on Synthetic Aperture Radar
Dresden, Germany, 16-18 May 2006
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July 2006

36th COSPAR Scientific Assembly
Beijing, China, 16-23 July 2006
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IRST2006 - Ionospheric Radio Systems and Techniques Conference
London, United Kingdom, 18-21 July 2006
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September 2006

Vertical Coupling in the Atmospheric/Ionospheric System
Varna, Bulgaria, 18-22 September 2006
Contact : Dr. Dora Pancheva, Centre for Space, Atmospheric & Oceanic Science, Dept. of Electronic and Electrical Engineering, University of Bath, Bath BA2 7AY, United Kingdom, Fax : +44 1225-386305, E-mail : eesdvp@bath.ac.uk, Web : http://www.iaga.geophys.bas.bg/

November 2006

EuCAP 2006 - European Conference on Antennas and Propagation
Nice, France, 6-10 November 2006
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December 2006

APMC 2006 - 2006 Asia-Pacific Microwave Conference
Yokohama, Japan, 12-15 December 2006
Contact : Takashi Ohira, 2-2-2 Hikaridai, Keihanna Science City, Kyoto 619-0288, Japan, Fax +81 774-95 1508, E-mail : ohira@atr.jp , Web : http://www.apmc2006.org

August 2007

ISAP 2007 - International Symposium on Antennas and Propagation
Niigata, Japan, 20-24 August 2007
Contact : Yoshihiko Konishi (Publicity Chair), Mitsubishi Electric Corporation, 5-1-1 Ofuna, Kamakura, 247-8501 Japan, E-mail isap-2007@mail.ieice.org,, Web : http://www.isap07.org and http://www.ieice.org/cs/isap/2007/

AP-RASC 2007 - Asia-Pacific Radio Science Conference
Perth, Australia, August - September 2007, exact date not fixed yet
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BOOK PUBLISHED BY AN URSI RADIOSCIENTIST

Advances in Electromagnetic Fields in Living Systems (Volume 4)

Edited by James C. Lin, Springer, ISBN 0-387-23997-9

Advances in Electromagnetic Fields in Living Systems, published by Springer since 1994, presents state-of-the-art discussions in electromagnetism that influence the activities of living organisms. This focus affirms Springer's commitment to publish important reviews to add to the scientific and professional literature-significant research that is larger in scope than journal articles.

Advances in Electromagnetic Fields in Living Systems, Volume 4 begins with fetal magnetocardiography (fMCG), a noninvasive method of detecting components of the magnetic field produced by the electrical activity of the fetal heart. fMCG is experiencing steady growth, and is expected to gain influence in diagnosing certain congenital fetal heart defects while at the same time providing optimal care for patients. fMCG provides a distinct signal, free of maternal cardiac interference, which can be detected throughout the last half of pregnancy.

Other Key Topics are: Noninvasive biomedical application of non-ionizing electromagnetic energy, Microwave thermoelastic imaging uses microwave-pulse-induced thermoelastic pressure waves to form planar or tomografic images, Mechanisms of light-tissue interaction in the near infrared region and different types of instruments used for diffuse optical imaging, Advances in reliable laser diodes and optical telemetry, ELF magnetic-field exposure and the pain system and Cyclotron resonance in enhancing the sensitivity of biological systems to magnetic fields.

Advances in Electromagnetic Fields in Living Systems will be essential reading for all academics, bench scientists, and industry professionals wishing to take advantage of the latest and greatest in this continuously emerging field.

About the Editor

Dr. James C. Lin is Professor of Electrical Engineering, Professor of Bioengineering, and Professor of Physiology and Biophysics at the University of Illinois, Chicago. Among other honors, Dr. Lin is a Fellow of IEEE, a Fellow of A.A.A.S, a Founding Fellow of AIMBE, and a recipient of the d'Arsonval Medal from the Bioelectromagnetics Society.

The Journal of Atmospheric and Solar-Terrestrial Physics

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

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