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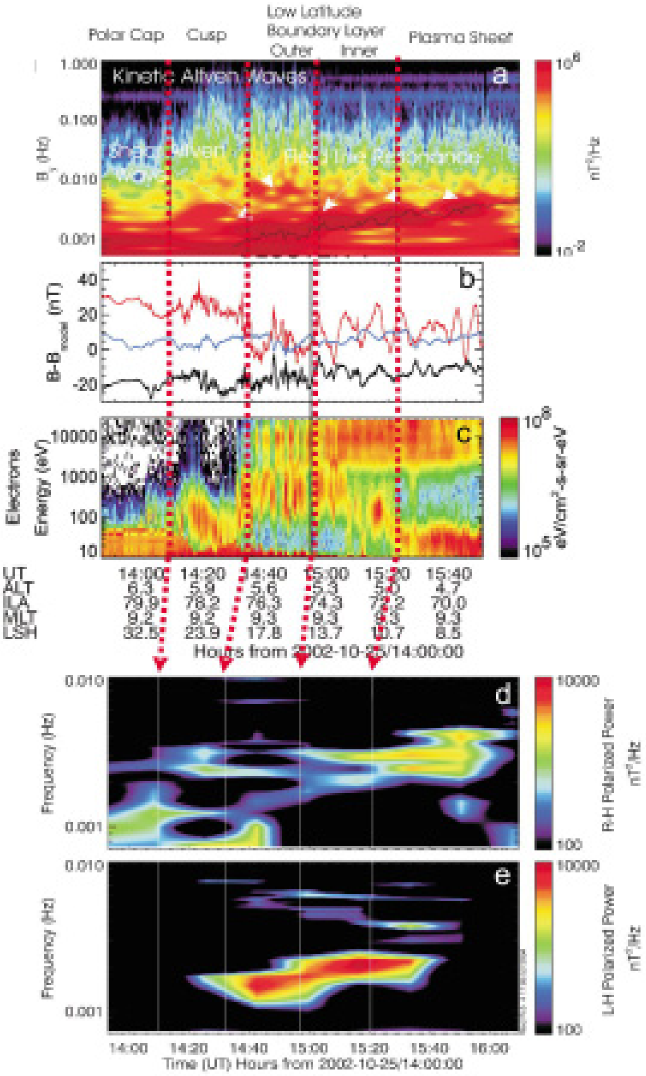

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Front cover: A mode-conversion case study. See the paper by Chaston on pp. 18 - 24.

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Editorial

We have three *Reviews of Radio Science* in this issue, Jim Lin's column, and the first radio science doctoral abstracts. With deep regret, we also have an "in memoriam" for Tor Hagfors, who was an active part of URSI for many years.

Our Papers

In their invited Commission E *Review*, Masashi Hayakawa and Oleg Molchanov introduce what they characterize as a new area of radio science: semiso-electromagnetics. This is the term they use for electromagnetic phenomena associated with earthquakes. They review primarily non-seismic methods for studying the short-term processes associated with earthquakes, and they also consider the possibility of using such methods to aid in forecasting earthquakes. They review the data indicating relationships between seismic activity and effects on ULF emissions observable from the ground, as well as perturbations in the atmosphere and ionosphere that can be detected by probing with VLF through HF radio waves. They also review effects seen in satellite observations of ionospheric turbulence and VLF and LF transmitter signals. They provide some interesting suggestions for the mechanisms that could trigger these phenomena, and show that the observations do provide precursors to seismic events. The efforts of the Associate Editor for Commission E, Christos Christopoulos, in bringing us this *Review* are gratefully acknowledged.

Shear Alfvén waves in the plasmas associated with the Earth's magnetosphere have several interesting properties. One of these is that they can carry an electric field parallel to the geomagnetic field. This permits motion of the plasma across the magnetic field, and can lead to mixing of plasmas across what have been traditionally viewed as impenetrable boundaries, such as the magnetopause. This electric field can also accelerate large beams of electrons that travel with the wave across the geomagnetic field, which in turn can drive aurora and cause a variety of plasma instabilities. In his invited Commission H *Review*, Christopher Chaston summarizes what is known about such waves, and in particular looks at the potential sources and processes for generating such waves. He is able to show that observations support mode conversion and reconnection as source mechanisms for dispersive shear Alfvén waves in the magnetosphere. This leads to the conclusion that the solar wind may drive processes in the magnetosphere and ionosphere via the energy transport associated with such waves. This is a fascinating *Review*, and it is written in such a fashion that a detailed knowledge of plasma physics isn't necessary to understand it. The efforts of the Commission H Associate Editor, Yoshi Omura, in bringing us this review are greatly appreciated.

Ultra-wideband radio is rapidly becoming a major factor in wireless communications. In their invited Commission C *Review*, Thomas Kaiser, Christiane Senger, Jens Schroeder, Stefan Galler, Emil Dimitrov, Mohamed El-Hadidy, and Bamrung Tau Sieskul bring us a broad overview of this important topic. They begin by considering impulse-radio ultra-wideband systems, and look at how the shape of the pulse used to transmit the data is related to the optimization of energy and the use of the available bandwidth. They then look at the variety of modulation schemes used for such systems, and how the choice of modulation is related to the channel model. The ultra-wideband channel in general is described, and the authors show how the almost-always-present multipath character of this channel can be used to improve communications. The authors then consider the potential advantages of splitting the available bandwidth into multiple bands. They show transmitter and receiver architectures for such a system, and look at the aspects of synchronization, channel estimation, and equalization. They then show how MIMO (multiple-input multiple-output) techniques can be used to further improve ultra-wideband communications. Finally, localization and position determination, along with their sources of error, are considered in some detail for such systems. This *Review* is written so that it should be understandable by those not working directly in the field, and it provides an excellent overview of this important emerging topic. The efforts of Takashi Ohira, Associate Editor for Commission C, in bring us this review are appreciated.

Of course, we have these reviews because of Phil Wilkinson's efforts in coordinating them.

Be sure to read Jim Lin's column on Radio-Frequency Radiation Safety and Health. He considers a recent publication from an INTERPHONE-related study that shows a connection between malignant brain tumors and long-term (more than 10 years) use of cell phones. This study, as well as an unrelated study from Sweden, both reported increased risk of malignant brain tumors associated with 10 or more years of cell-phone use.

Peter Watson brings us our first radio-science doctoral abstracts in his new column in this issue. The purpose of this column is both to make the radio-science community aware of the newest research, as well as to give the new radio scientists doing the research an opportunity to become known within our community. I hope this leads to better communication and involvement within our community.

This issue was delayed a bit because of preparations for the URSI Board and Coordinating Committee meetings held in April. The Coordinating Committee is planning an excellent, exciting program for the 2008 URSI General Assembly to be held in Chicago. An announcement of the General Assembly appears in this issue. Please start planning now to participate. The call for papers should be out by the end of May, and will appear in the next issue.

The *Radio Science Bulletin* is still actively seeking papers of broad interest to radio scientists. Please consider sharing your results with our readers. If you have a contribution, simply send it to me.

Ross

An Invitation: Join the URSI Web Lectures Initiative

URSI plans to develop a library of electronic lectures that will be made available through an Internet interface. This initiative is currently in an early stage, and will be developed over the next year.

Electronic lectures, or Web lectures as they are more commonly called, embrace all the different ways a normal lecture presentation is captured for remote or delayed viewing. Over the last decade, many groups have explored ways of distributing video lectures. Early versions used a single video camera to capture images of both the lecturer and the screens used by the lecturers during their presentations. In developing this approach for display in a Web browser, a number of techniques been developed to enhance the presentation. URSI is interested in exploring all of these options, including the earlier direct video capture converted to a suitable Web browser format.

The lectures will cover all URSI Commission areas of interest. Topics may be treated at a tutorial or introductory level. The electronic format of the lectures may range from *PowerPoint* (including sound files) to streaming video, with the simpler formats being favored.

At this stage, we are seeking examples of Web lectures and suggestions from people familiar with this mode of outreach. You are invited to join this initiative by submitting an electronic lecture for addition to the URSI library of lectures. Your submission will be treated as a publication, and will undergo a review procedure similar to that used for *Radio Science Bulletin* submissions.

Please send your submission or comments to Dr. Phil Wilkinson, e-mail: phil@ips.gov.au.

XXIX General Assembly of the International Union of Radio Science

Union Radio Scientifique Internationale

August 07-16, 2008
Hyatt Regency Chicago Hotel on the Riverwalk
151 East Wacker Drive, Chicago, Illinois 60601, USA

First Announcement

The XXIX General Assembly of the International Union of Radio Science (Union Radio Scientifique Internationale: URSI) will be held at the Hyatt Regency Chicago Hotel in downtown Chicago, Illinois, USA, August 07-16, 2008.

The General Assemblies of URSI are held at intervals of three years to review current research trends, present new discoveries and make plans for future research and special projects in all areas of radio science, especially where international cooperation is desirable. The first Assembly was held in Brussels, Belgium, in 1922, and the latest in New Delhi, India, in 2005. Assemblies were held in the USA on three previous occasions: in Washington, DC, in 1927 and 1981, and in Boulder, Colorado, in 1957.

The XXIX General Assembly will have a scientific program organized around the ten Commissions of URSI and consisting of plenary lectures, public lectures, tutorials, invited and contributed papers. In addition, there will be workshops, short courses, special programs for young scientists and graduate students, and programs for accompanying persons. More than 1,500 scientists from more than fifty countries are expected to participate in the Assembly.

The Call for Papers will be issued in mid-2007, will be published in the *Radio Science Bulletin* and in the *IEEE Antennas and Propagation Magazine*, and will be posted on the URSI Web site. It is expected that all contributions should be received by the end of January, 2008, and that authors will be notified of the disposition of their submissions by the end of March, 2008.

http://www.ursi.org

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UNION RADIO-SCIENTIFIQUE INTERNATIONALE

INTERNATIONAL UNION OF RADIO SCIENCE

AWARDS FOR YOUNG SCIENTISTS

CONDITIONS

A limited number of awards are available to assist young scientists from both developed and developing countries to attend the General Assembly of URSI.

To qualify for an award the applicant:

1. must be less than 35 years old on September 1 of the year of the URSI General Assembly;
2. should have a paper, of which he or she is the principal author, submitted and accepted for oral or poster presentation at a regular session of the General Assembly.

Applicants should also be interested in promoting contacts between developed and developing countries. Applicants from all over the world are welcome, also from regions that do not (yet) belong to URSI. All successful applicants are expected to participate fully in the scientific activities of the General Assembly. They will receive free registration, and financial support for board and lodging at the General Assembly. A basic accommodation is provided by the assembly organizers permitting the Young Scientists from around the world to collaborate and interact. Young scientists may arrange alternative accommodation, but such arrangements are entirely at their own expense. Limited funds will also be available as a contribution to the travel costs of young scientists from developing countries.

All Young Scientists should apply via the web-based form which will appear when they check "Young Scientist paper" at the time they submit their paper. All Young Scientists must submit their paper(s) and this application together with a CV and a list of publications in PDF format to the GA submission Web site.

Applications will be assessed by the URSI Young Scientist Committee taking account of the national ranking of the application and the technical evaluation of the abstract by the relevant URSI Commission. Awards will be announced on the URSI Web site in April 2008.

For more information about URSI, the General Assembly and the activities of URSI Commissions, please look at the URSI Web site at: http://www.ursi.org. If the information you are looking for is not on this site, please contact:

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APPLICATION FOR AN URSI YOUNG SCIENTIST AWARD

I wish to apply for an award to attend the XXIXth General Assembly of the International Union of Radio Science in Chicago, Illinois, USA, on 9-16 August 2008.

Name: Prof./Dr./Mr./Mrs./Ms. ....

Family Name First Name Middle Initials

Sex: male / female

Nationality: ....

Studying/Employed at: ....

Institution ....

Department..

Mailing address: Please send all correspondence to my ☐ business / ☐ home address, i.e.

Street ....

City and postal code ....

Province/State .... Country ....

Fax .... E-mail ....

Academic qualifications, with date(s) obtained: ....

....

Title of abstract submitted: ....

....

Type of session preferred: ☐ in an oral session ☐ in a poster session

The subject of the paper is relevant to URSI Commission ……….session (leave blank if uncertain).

I hereby certify that I will be less than 35 years old on September 1, 2008.

Date:............................ Signed: ....

For applicants from developing countries only:
I estimate the cheapest return fare to the URSI meeting is EURO...

Seismo-Electromagnetics as a New Field of Radiophysics: Electromagnetic Phenomena Associated with Earthquakes

M. Hayakawa
O.A. Molchanov

Abstract

Short-term earthquake prediction is an urgent subject for human beings, but it is concluded that conventional seismologic and geotectonic measurements are not suitable for such prediction. Recently, electromagnetic phenomena have been recognized as being very promising for such short-term earthquake prediction. A lot of convincing evidence has been accumulated on electromagnetic phenomena associated with earthquakes (we use the general terminology of seismo-electromagnetics). This short review deals with only a few important phenomena, including radio-physical methods of atmospheric and ionospheric sounding with the use of signals from VLF, LF, and HF transmitters; ground-based recording of pulsating ULF electromagnetic emission (so-called ULF foreshocks); and onboard plasma variations on low-orbiting satellites.

1. Introduction

An earthquake (EQ) is probably the most disastrous natural phenomenon. As presented in Figure 1 (where white rectangles indicate the number of earthquakes, and black rectangles represent the death toll), the death toll from large earthquakes during the last century exceeded two million people. The corresponding geography of the most damaging earthquakes included 25 countries. The first ten of these were Iran; China; Turkey; Japan; India; Italy; the former USSR (Russia, Turkmenistan, Armenia areas); Indonesia; Afghanistan; and Pakistan. The others were Chile, Algeria, Colombia, Peru, Guatemala, The Philippines, Nicaragua, Romania, Morocco, Mexico, Argentine, USA, Jamaica, Yugoslavia, and El Salvador. During the recent 10 years, from 1995 to the beginning of 2006, there were more than 400,000 people killed by earthquake catastrophes, and the geographic distribution of the damaging earthquakes did not change a lot.

The origin of an earthquake is still not clear, and the problem of its forecasting is urgent. For a rather long time, the scientific community has relied mainly upon traditional Earth science disciplines in solving this problem: seismology, tectonics, geodynamics, and so on. However, about 15 years ago, a conceptual breakdown happened in seismology. It was discovered that conventional models of earthquake

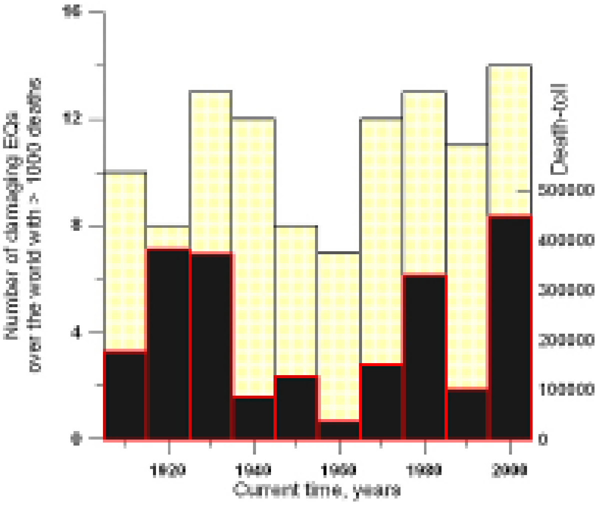

Figure 1. The number of damaging earthquakes (with more than 1000 deaths) and the death toll during the last 100 years, from 1906 to the beginning of 2006 (data from USGS catalog).

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This is one of the invited *Reviews of Radio Science,* from Commission E.

preparation were not valid, and doubts began to appear as to the possibility of successful earthquake prediction using purely seismic observations. Heterogeneity and nonlinearity in seismic processes in a state of so-called self-organized criticality, causing unpredictable behavior of a tectonically activated region after some time of consideration (the limited "memory" of the system), became understood. At the same time, some ideas on new alternative field methods, with particular emphasis on radio-physical sounding and even satellite observations, emerged. These gradually took the place of traditional studies on the quasi-steady electric and magnetic fields, resistivity, magneto-telluric impedance, and geodetic changes, which were found to be inefficient. By that stage, enthusiastic groups in several countries had already shown evidence of seismo-electromagnetic phenomena.

2. Seismo-Electromagnetics and Related Phenomena

As a result, a new approach to studying seismo-electromagnetic phenomena has recently emerged, called *Seismo-electromagnetics and related phenomena* (SERP). This is a study of short-term processes of the earthquake sequence by mainly non-seismic methods. This field has become firmly established since the early 1990s. It differs from its predecessor, which was known for a long time as the non-seismic precursors of earthquakes, both in methods and ideology. Modern technologies for registration of seismically induced perturbations and proper data processing are applied. First of all, these are radio-physical methods of atmospheric and ionospheric sounding by means of radio signals from VLF, LF, and HF transmitters. Pulsating ULF electromagnetic and seismo-acoustic emissions (the so-called ULF and acoustic foreshocks), and higher-frequency emissions on the ground and onboard plasma variations on low-orbital satellites, are then recorded. These data, together with closely related data on hydrology/geochemistry in wells and hot springs, satellite remote sensing of the ground surface, and atmosphere parameters, comprise the factual basis of the research. Two main problems are suggested, as follows: (1) the mechanisms of strong intra-plate earthquake triggering, and (2) lithosphere-atmosphere-ionosphere coupling due to seismicity.

There were at least three reasons for attracting our attention and enlarging the scope of this type of research. The first was the discovery of several intriguing observational facts. Among these, it is worth mentioning the almost simultaneous finding of specific ultra-low-frequency (ULF) electromagnetic emissions before and after the large Loma Prieta earthquake in the USA [1], and around the date of the large Spitak earthquake in the former USSR [2]. The results in both countries looked very similar, and they were therefore convincing [3]. In 1990, Fraser-Smith et al. [1] observed intensive ULF emissions practically above the hypocenter of the earthquake, which was at a depth of about 10 km. Figure 2 is adapted from their paper, and indicates the first enhancement two to three weeks before the earthquake, and a second sharp increase just before the earthquake. The geomagnetic activity before the earthquake was very quiet, so they concluded that these ULF emissions were likely to be an earthquake signature. A noticeable impact was also produced by the discovery of clear seismic-induced perturbations near the atmosphere-ionosphere boundary with the use of VLF transmitter signal sounding before the famous Kobe earthquake in Japan [4]. This effect was proven by subsequent statistics before eleven great earthquakes [5]. The left panel in Figure 3 refers to this Kobe earthquake. The shift in the terminator time (which is defined as the time when there is a minimum in amplitude and in phase in the diurnal variation just around sunrise and sunset) (here, we use the evening terminator time, around sunset, from the corresponding monthly mean value) was plotted on the ordinate in hours (the upper plot is the phase data, and the lower plot is the amplitude data). The blackened area means that we observed a very significant shift in the evening terminator time with the use of a 2σ criterion, where σ is the monthly standard deviation. Similar phenomena were also observed for another earthquake in 1978 (the right panels in Figure 3 [5]).

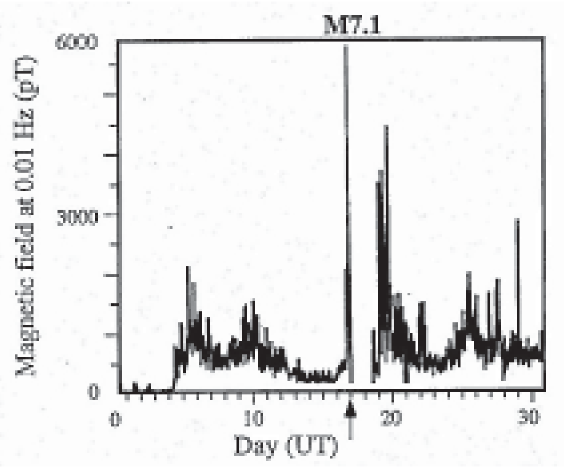

Figure 2. The ULF magnetic field at a particular frequency of 0.01 Hz, recorded on a single induction coil during October, 1989. The arrow shows the time of the Loma Prieta earthquake (M = 7.1, October 17, 1989). Registration was produced at a distance of 7 km from the earthquake's epicenter (after Fraser-Smith et al. [1]).

The second reason was that the Japanese government established special research programs to investigate short-term (at least) earthquake forecasting after the shock and sorrow following the great Kobe earthquake. This was driven by a general demand from the Japanese people for warnings of such disastrous events. These programs included the Frontier/RIKEN and Frontier/NASDA projects, which investigated electromagnetic and some other effects associated with seismicity. Many valuable results were obtained, and two networks of ULF and VLF stations in Japan were developed. However, it was perhaps most important that these projects promoted an international

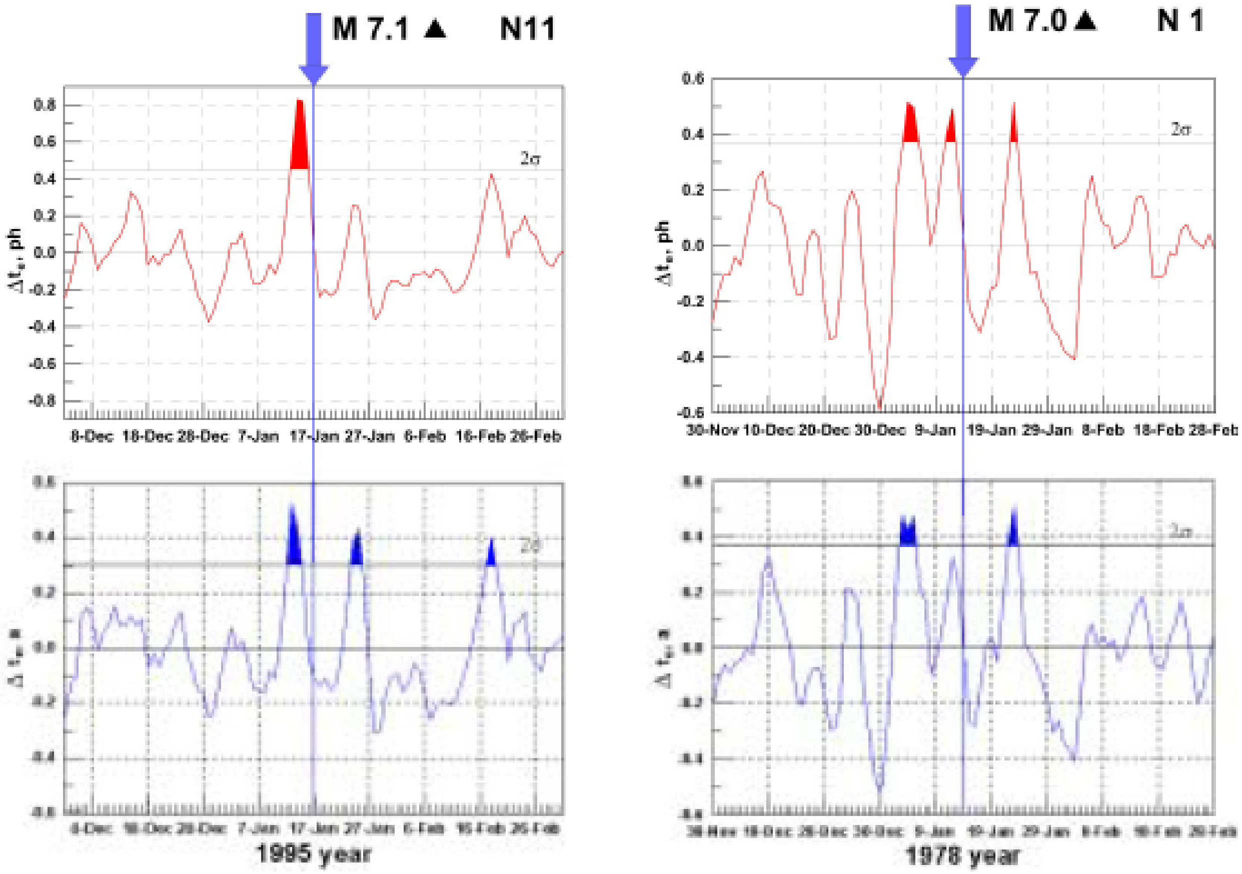

Figure 3. A comparison of the phase and amplitude VLF signal variations (as a function of the change in terminator time) before and after the Kobe earthquake (January 17, 1995; M = 7.1, left panel) and similarly for the great earthquake in 1978 (right panel), in an interval of ±45 days, with a 10-day grid.

consolidation of the research on seismo-electromagnetics. Special symposia in Chofu, Tokyo, were attended by specialists from about 20 countries (see the comprehensive collection of papers edited by Hayakawa and Fujinawa in 1994 [6], by Hayakawa in 1999 [7], and by Hayakawa and Molchanov in 2002 [8]). Similar research projects followed in Taiwan, India, Italy, and Russia. In the framework of a Japanese-Russian collaboration, a special station, Karymshino, was established in the Kamchatka peninsula (in far-eastern Russia). It is designed for regular complex monitoring (including local seismicity, ULF electric and magnetic field variations, seismo-acoustic emission, VLF transmitter signals, hydrology and geochemistry changes in the wells and springs, and atmospheric parameters), in addition to data on regional seismicity (27 stations). The station is situated in a rural place with low industrial interference, but with frequent seismicity. At present, it is considered a reference station for Japanese networks [9].

The third reason was the realization of an exclusive satellite mission, DEMETER, in France. The satellite was designed for the investigation of electromagnetic effects related to earthquakes, and anthropogenic electromagnetic-wave influences on the ionosphere. Pre-seismic electromagnetic effects observed on satellites were first reported in Russia (e.g., [6]), and they were then intensively discussed during the preparation of DEMETER and in the framework of the Frontier/NASDA project in Japan. This pioneering satellite was at last launched on June 29, 2004 (its artistic illustration is given in Figure 4; for details, see

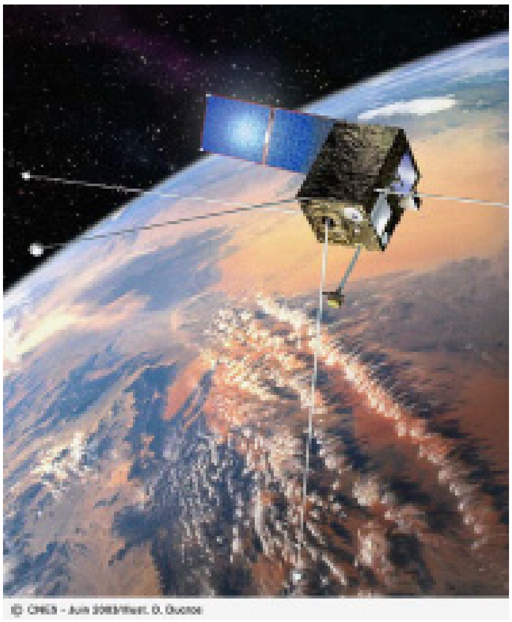

Figure 4. An artistic view of the DEMETER satellite (adopted from the CNES Web site).

N	Place of EQ	Date	M	Depth km	Distance km	Pre-Seismic Time	Near-Seismic Time	References
1	Spitak, Armenia	8.12.1988	6.9	6	130	No	4 hours	[1]
2	Loma-Prieta, USA	17.10.1989	7.1	15	7	12 days	3 hours	[2]
3	Northridge, USA	17.01.1994	6.7		90	No	No	[12]
4	Northridge, USA		6.9		205	No	No	[12]
5	Hector Mine, USA	16.10.1999	7.1		140	No	No	[13]
6	Guam	8.08.1993	8	60	85	4 weeks	No	[14]
7	Biak, Indonesia	17.02.1996	8.2	20	110	A few months	No	[15]
8	Kagoshima, Japan	3.03.1997	6.5	20	70	A few weeks	No	[16]
9	Izu, Japan	4.05.1998	5.7	10	35	A few weeks	No	[16]
10	Matsushiro, Japan	1.07.1998	4.5	20	23	No	1 day	[17]
11	Iwata, Japan	3.09.1998	6.1	10	17	16 days	No	[16]
12	Chi-chi, Taiwan	21.09.1999	7.7	10	140	A few weeks	No	[18]
13	Izu swarm, Japan	1.07.2000	6.4	1	75	2 months	2 days	[19]
14	Erimo, Japan	20.02.1997	5.7	20	60	No	No	[20]
15	Okushiri, Japan	12.07.1993	7.8		310	No	No	[20]

Table 1. A case study of ULF magnetic-field variations related to large earthquakes.

http://smsc.cnes.fr/DEMETER/GP_satellite.htm), with the intension of studying seismically associated plasma and wave phenomena [10], Numerous data are now being analyzed by French specialists and guest investigators in different countries.

A comprehensive review of the SERP activity was presented by Molchanov and Hayakawa in 2006 [11]. This book summarized results of the studies, especially those that were obtained in Japan and Russia. After the Introduction (Chapter 1), Chapter 2 was devoted to effects originating in the ground and near the ground's surface. In Chapter 3, the effects observed on the ground but induced by perturbations in the atmosphere and ionosphere were discussed. Observations onboard satellites and their interpretation were presented in Chapter 4. Finally, some discussion on earthquake prediction and triggering was presented in Chapter 5.

Here, we are going to mention several important problems that can be studied with radio-physical methods.

2.1 Generation and Propagation of ULF Pulses in the Ground Associated with Seismicity

Following the pioneering work of Fraser-Smith et al. [1] and Kopytenko et al. [2], there were other attempts to find ULF ($f = 0.003 - 3$ Hz) pulsating emissions related to large earthquakes. A list of the published reports is summarized in Table 1. As can be seen from Table 1, the number of convincing ULF signatures of earthquakes has increased in recent years. The distances from the epicenter to the observation point and the earthquake's magnitude are shown in Figure 5, as based on the ULF events in Table 1. This suggests some limiting distance for the reception of ULF seismically-related emissions. The near-seismic times in Table 1 refer to a lead time of less than a few hours (just before the earthquake), and the pre-seismic time indicates a few weeks to a few days. Cases with the presence of a pre-seismic ULF effect are depicted by open circles, while the solid circles refer to the cases with the absence of pre-

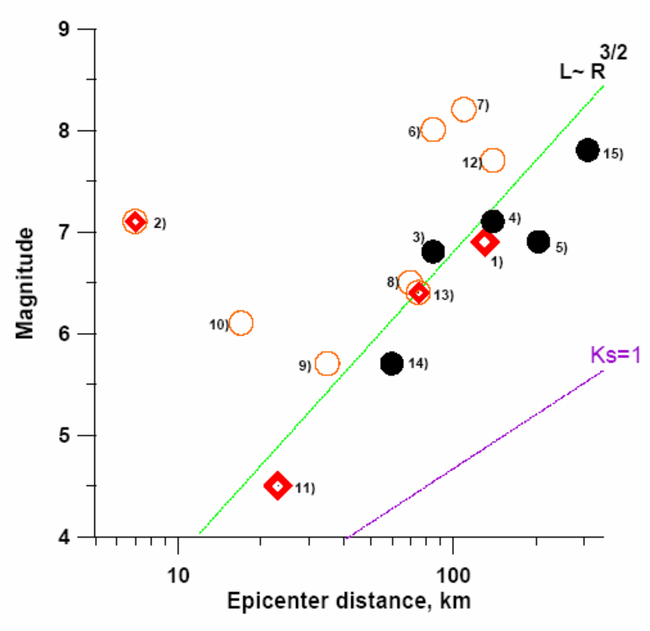

Figure 5. A summary diagram of the ULF magnetic-field case studies. Cases with the presence of pre-seismic effects are depicted by open circles, while the absence is shown by solid circles. Situations where only near-seismic ULF emission was found are shown by big diamonds. Open circles with small diamonds indicate where both effects were found. The threshold reception distance is approximately described by the line $L \sim R^{3/2}$ ($R \approx 8L^{2/3}$), where L is a size of the seismic source. This is noticeably less than the size of the precursory region (seismic index $Ks = 1$). Figures near circles or diamonds correspond to those in Table 1 (adapted from Hattori et al. [20]).

seismic ULF emissions. Big diamonds indicate a finding of only near-seismic ULF signatures. Open circles with small diamonds indicate the cases when both pre-seismic and near-seismic ULF emissions were detected. We can estimate a threshold reception distance, R (the upper line in Figure 5), which is described by $L \sim R^{3/2}$ (where L is a size of the seismic source).

Let us discuss the mechanisms of ULF radiation. There is a vast literature on stress-induced mechanisms related to the origin of long-term quasi-steady fields: piezo-magnetic conversion, piezoelectricity, mechanisms of defect polarization, triboelectricity, and so on [21]. However, for the explanation of short-term SERP effects, we can assume the loading stress as a constant, without any accumulation or consolidation, and we consider mechanisms connected with only pre-seismic fracturing and fluid movement. So, we mention three possible mechanisms.

1. The first mechanism of fracturing emission, i.e., an unbalanced charge creation and its relaxation during the fast opening of the fracture, can be considered. This mechanism was supported by the results of a number of laboratory experiments in which electromagnetic radiation, together with seismo-acoustic emission in the nearly the same frequency range, were observed from ground-medium samples under appropriate pressure loading. This mechanism was suggested by Warwick et al. [22], who explained high-frequency radiation ($f \sim 10$ MHz) that was observed during the great Chilean earthquake in 1960 ($M \sim 8.0$). As an application to ULF magnetic-field radiation, a similar model with some modifications concerning charge relaxation and averaging over an ensemble of microfractures was discussed by Molchanov and Hayakawa [23]. They estimated the dependence of the averaged source current density, $\mathbf{j}_s$, on the fracturing properties.
2. The second mechanism is a mechanism of inductive electromagnetic fields, arising during the course of seismic-wave propagation in the conductive ground medium after fracture opening. This inductive-current mechanism was recently discussed intensively (e.g., [24]) as a candidate for co-seismic and near-seismic ULF magnetic and electric field variations. The electric field induced in the conductor moving with velocity **v** under the permanent Earth's magnetic field $\mathbf{H}_0$ is known to be

$$E' = \mu \mathbf{v} \times \mathbf{H}_0,$$

supposing that $H \ll H_0$, where H is the perturbation magnetic field. In our case, $\mathbf{v} = \partial \mathbf{u} / \partial t$, where **u** is a vector of the ground displacement produced by a seismic wave. The resultant source current is given as follows:

$$\mathbf{j}_s(\mathbf{r}, t) = \sigma \mathbf{E}' = \left(\partial \mathbf{u} / \partial t \times \mathbf{H}_0 \right) / D_m,$$

where $D_m = (\sigma \mu)^{-1}$ is the coefficient of magnetic-field diffusion and s is the ground conductivity.

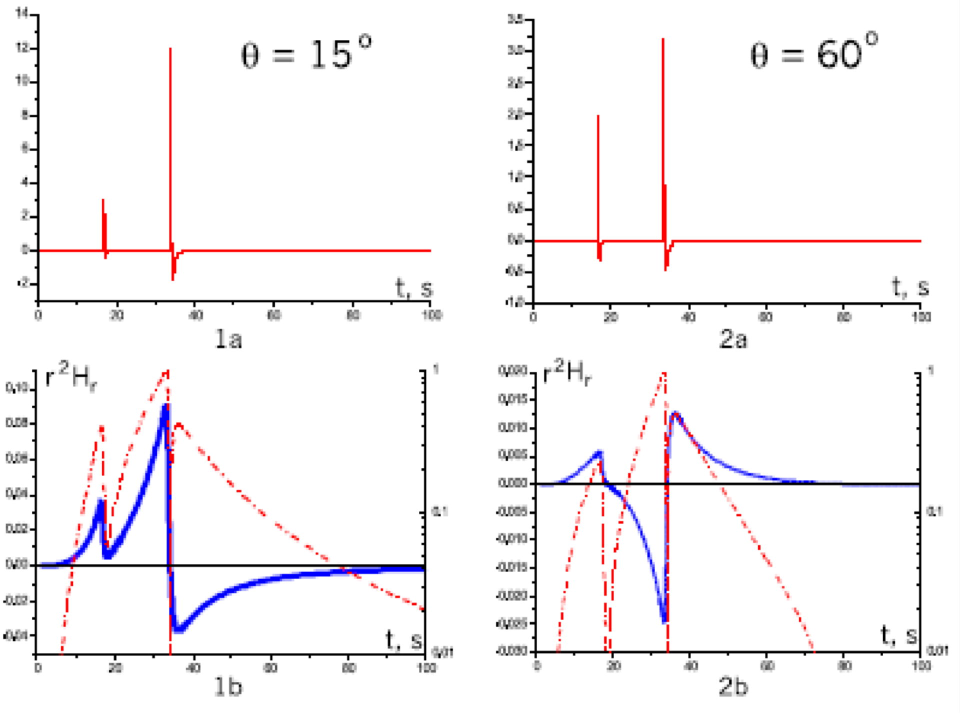

Figure 6. The computed temporal evolution: a) Seismic pulses from a fracture with a size of $L = 3$ km at a hypocentral distance $r = 100$ km, neglecting elastic scattering; b) The amplitude of a coseismic magnetic field pulse H_r, normalized to r^{-2}. The dash-dotted lines show the value of $|H_r / H_{rmax}|$ on a logarithmic scale. We assumed $C_p = 6$ km/s, $C_s = 3$ km/s, and $D_m = (\mu \sigma_g)^{-1} = 200$ km²/s. The left panels are for a dip angle of the Earth's magnetic field of $\theta = 15°$, while the right panels are for $\theta = 60°$ (adapted from Molchanov et al. [28]).

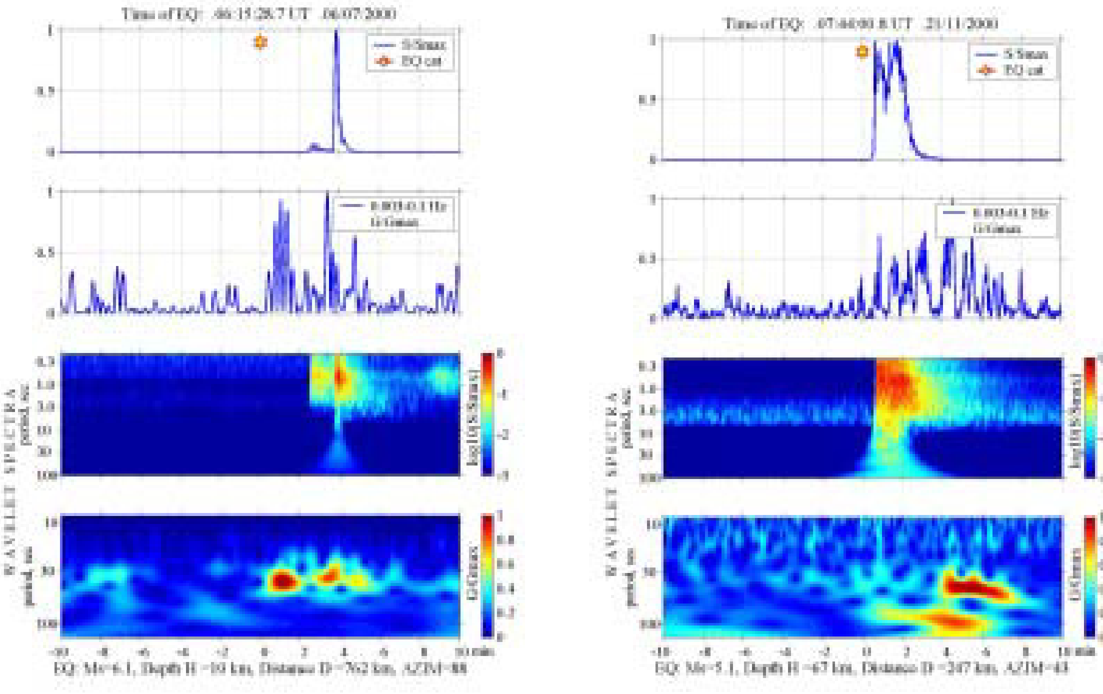

Figure 7. Two examples of coseismic registration at Karymshino station in a time interval of ± 10 minutes around the earthquake moment. The upper panel is the seismometer recording: a yellow star is the time of the earthquake. The next panel shows the relative intensity of the horizontal component of the ULF magnetic field in the frequency range of 0.003-0.1 Hz. The third panel is the corresponding wavelet spectrum of the seismic recording in a range of periods of 0.3-100 s, and the lower panel is the wavelet G component spectrum for the periods of 10-200 s. a) The case of an earthquake with $M = 6.1$*, distance 762 km, depth 10 km; b)* $M = 5.1$*, distance 247 km, depth 67 km.*

3. The third mechanism is a mechanism of electro-kinetic (EK) conversion due to fluid diffusion in a porous and fractured ground. This mechanism was suggested by Mizutani et al. [25] in order to interpret slow geopotential variations. The basic parameters of the mechanism were also checked in laboratory experiments [26, 27]. The electro-kinetic effect is just the reverse of the electroosmose and has been known for more than 70 years. It originates due to the appearance of an electric double layer formed at the solid/liquid interface during the movement of the liquid. The double layer is made up of a layer of ions (the Helmoltz layer), absorbed on the surface of the rock, and of a diffuse mobile layer (the Gouy-Chapman zone), extended into the liquid phase. When a fluid is made to flow through a porous medium there will be an occurrence of a potential – the so-called streaming potential – across the sample, because of the relative motion between the solid and the liquid.

While electric and magnetic fields in the conductive ground medium can be expressed through vectorial and scalar potentials $\mathbf{A}$, φ $\left(\mathbf{H} = \nabla \times \mathbf{A}, \mathbf{E} = -\nabla\varphi - \mu\,\partial\mathbf{A}/\partial t\right)$, their propagation indeed follows the type of diffusion and convection. For example, the evolution of the vector potential $\mathbf{A}$ is described by the following equation:

$$\nabla^2\mathbf{A} - (\nabla\sigma/\sigma)\nabla\cdot\mathbf{A} - (\partial\mathbf{A}/\partial t)/D_m = -\mathbf{j}_s\,.$$

This leads to a specific dispersion of electromagnetic pulses. Some results of computations for a coseismic pulse due to the second generation mechanism are shown in Figure 6 [28], where the duration of a seismic pulse is equal to the initial electromagnetic-pulse duration in the source. A comparison of the upper and lower results clearly indicates the dispersion of the ULF electromagnetic pulse. Some examples of real data observed at Karymshiro observing station are shown in Figure 7. Two examples of coseismic registration are illustrated in the time interval ±10 min around the earthquake moment. The top panel indicates the seismometer record (a yellow star refers to the time of the earthquake), and the next panel shows the ULF magnetic-field intensity in the frequency range of 0.003-0.1 Hz. The third panel is the corresponding wavelet spectrum of the seismic record. The wavelet G-component spectrum is at the bottom. Both in the observations and in the computations, the electromagnetic pulse was found to be longer than the seismic pulse, and appeared earlier at the registration point.

2.2 Sounding of Seismically-Induced Atmospheric/Ionospheric Perturbations by Radio Signals

Seismically-associated perturbations in the upper atmosphere and ionosphere were revealed using sounding

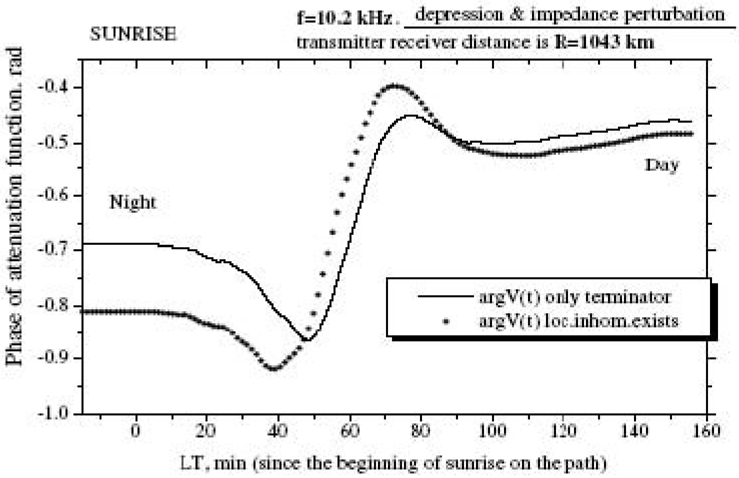

Figure 8. The computed VLF signal phase (the phase of the attenuation function) as a function of the local time (LT) since the beginning of sunrise on the path. The observation situation in Japan was modeled. The resulting terminator-time change at sunrise was $\Delta t \sim 12$ *minutes, which led to the extension of daytime conditions (adapted from Soloviev et al. [32]).*

with VLF signals ($f = 10-40$ kHz, Hayakawa et al. [4]) and LF broadcasting signals ($f = 189-270$ kHz, Biagi et al. [29]). The perturbations in the troposphere were found from HF over-the-horizon propagation ($f = 50-90$ MHz [30, 31]). These results are in compliance with the theoretical model in which seismogenic atmospheric oscillations and related radio-signal characteristics are induced by atmospheric gravity waves, generated during the processes of earthquake preparation and relaxation (see the detailed discussion in Molchanov and Hayakawa [10]). Hayakawa et al. [4] suggested a special terminator-time (TT) method for the analysis of VLF signals. Their terminator-time method was checked by Soloviev et al. [32]. They presented a mathematical model, an asymptotic theory, and an appropriate numerical algorithm to study a VLF point-source field-propagation problem in the scalar approximation within the nonuniform Earth-ionosphere waveguide. They took into account a three-dimensional local ionospheric inhomogeneity over the ground at the solar-terminator transition. The local ionospheric perturbation, the center of

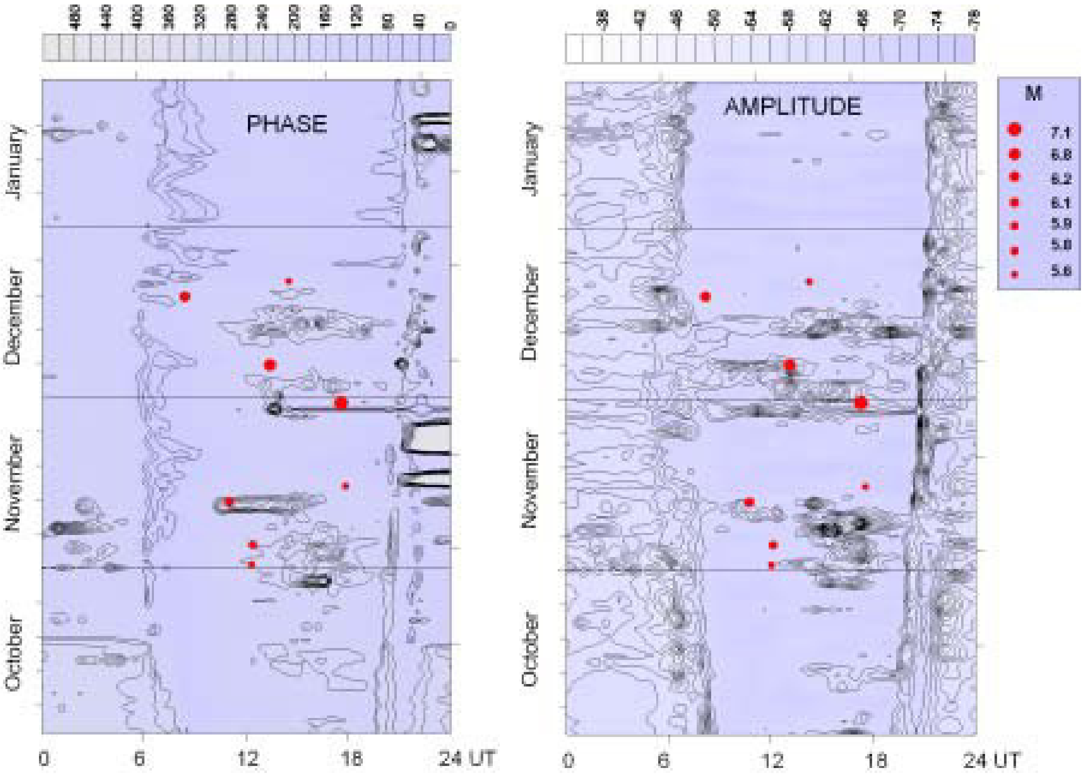

Figure 9. A contour map of the variations in the LF signals ($f = 40$ kHz) on the wave path of Japan-Kamchatka during the strong seismic activity in November-December 2004. The local time was UT+9.5 hours. The circles are the local time and dates of the strong earthquakes near the wave path of Japan-Kamchatka. Any erosion of the terminator transition in both the phase and amplitude variations was probably connected with the seismicity that coincided with observation data presented by Hayakawa et al. [4] and Molchanov and Hayakawa [5].

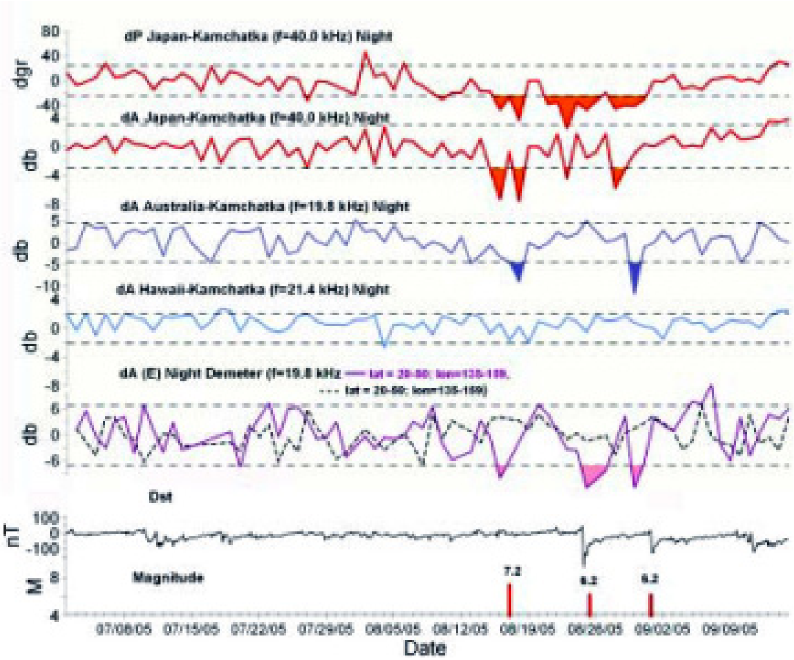

Figure 10. The VLF signal differences in the ground observations for the wave path Japan-Kamchatka (two upper panels), and for the wave paths of the NWC (Australia) and NPM (Hawaii) transmitters (the next two panels). The fifth panel is the VLF signal observed onboard the DEMETER satellite by reception of the NWC transmitter signal, electric field recording $dA(E)$: the solid line in the fifth panel is for the data above Japan, and the dash-dotted line is for the data away from the area of Japan. The two panels below are the Dst variation and the earthquake magnitude values

which was situated above the model earthquake epicenter, was simulated by a bell-shaped impedance inhomogeneity of the ionospheric-waveguide wall. Some examples of their computations are presented in Figure 8. Figure 8 is the computational result for simulating the Kobe earthquake case, and the authors found that the lowering of the ionosphere leads to the enlargement of the daytime, while the uplift of the lower ionosphere leads to the shortening of the daytime. This result supports the previous observation results by Hayakawa et al. [4] and Molchanov and Hayakawa [5], in which they found a significant terminator-time shift.

Recently, Rozhnoi et al. [33] extensively elaborated the terminator-time changes in sub-ionospheric VLF/LF propagation. By using the observation at Kamchatka of the sub-ionospheric LF transmitter in Japan (JJY transmitter, $f = 40$ kHz), they found terminator-time changes in possible association with earthquakes within the second Fresnel zone of the great-circle path. The results are shown in Figure 9. The period of October 2004 through January 2005 was analyzed (left, phase; right, amplitude), and an erosion of terminator-time transition in both the phase and amplitude variations is likely to be associated with the seismicity. The magnitude earthquake is shown to be proportional to its size.

2.3 VLF Signal Scattering in the Ionosphere Observed by Satellite

Reception of VLF signals was undertaken on many satellites for the investigation of VLF wave propagation and interaction with ionospheric plasma (e.g. [34, 35]). However, when we apply this method to long-time seismic effects, we need special data processing, both onboard a satellite and on the ground, in addition to the reception itself. Therefore, this can be considered to be a new method of ionospheric sounding in association with seismicity. Several years ago, this method, in combination with ground-based VLF signal reception, was suggested for a perspective satellite DEMETER, the major scientific objectives of which are to study ionospheric disturbances in relation to seismic activity, and to examine pre- and post-seismic effects. The results of observations, together with the new data processing, were described in Molchanov and Hayakawa [11]. An example of this kind of analysis is shown in Figure 10.

In Figure 10, the first two panels (from the top) illustrate the VLF information for the wave path, Japan-Kamchatka, and the next two panels refer to the two different wave paths from NWC (Australia) and NPM (Hawaii) to Kamchatka. The fifth panel was obtained from the DEMETER observation of the NWC transmitter signal in the form of the electric-field intensity at the transmitter frequency ($f = 19.8$ kHz). The solid line refers to the data over Japan, while the dashed line is the data away from Japan (for the sake of comparison). The bottom two panels are (1) the Dst variation as a measure of geomagnetic activity and (2) the earthquake occurrence in Japan and its magnitude. It can be seen from the figure that an evident decrease in VLF signal intensity, both on the ground and onboard the DEMETER satellite, could have happened in possible association with seismicity and geomagnetic activity (storms). However, we think that seismic forcing is more likely when we notice the absence of such a decrease in the Hawaii recording (for the ground observation).

Our explanation of the above-mentioned effect is as follows:

- We believe that this initial agent is an upward energy flux of atmospheric gravity waves (AGWs), which are induced by any geochemical quantity, such as gas-water release from an earthquake preparatory zone [11].

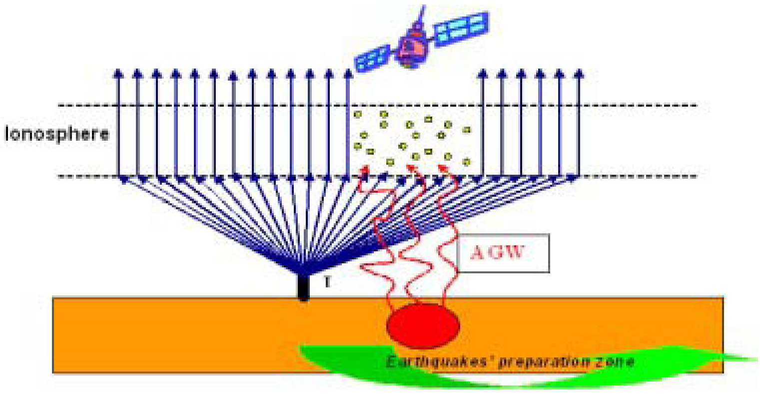

Figure 11. A schematic illustration of the VLF signal scattering supposed for the explanation of the observed effect, including atmospheric gravity waves (AGW) above the earthquake preparatory zone and modification of the ionospheric turbulence.

- Penetration of atmospheric gravity waves into the ionosphere leads to modification of the natural (background) ionospheric turbulence, especially for spatial scales of $\sim 1-3$ km and wavenumbers of $k_T \sim 10^{-4} - 10^{-3}$ m^{-1}. This weak but reliable effect is revealed from some direct satellite observations cited above [36, 37].
- Resonant scattering of the VLF signals is possible on the condition of frequency-wavenumber synchronism:

$$\omega_0 = \omega_s + \omega_T ,$$

$$\mathbf{k}_0 = \mathbf{k}_s + \mathbf{k}_T ,$$

where ω_0 and $\mathbf{k}_0$ are for the incident wave, ω_T and $\mathbf{k}_T$ are for the turbulence, and ω_s and $\mathbf{k}_s$ are for the scattered waves. It can be found that the amplitude of the incident wave, A_0, decreases exponentially during the course of propagation thorough the perturbed medium: $A_0 \sim \exp\left(-\alpha_n A_T H\right)$, where α_n is a coefficient of nonlinear interaction and H is the length of the interaction region. In our case of VLF signals, $\omega_T \ll \omega_0 \sim \omega_s$, and the interaction is especially efficient because of $k_0 \sim k_s \sim k_T$ (see, e.g., [38, 39]). Therefore, even though the amplitude of the turbulence, A_T, is small, the scattering could be significant if the length, H, is large. An artistic view of this coupling mechanism is depicted in Figure 11.

3. Conclusion

In this review, we have paid our greatest attention to a few selected topics: ground-based observation of acoustic and ULF emissions, radio probing of atmospheric and ionospheric perturbations by means of transmitter signals in different frequency ranges (VLF/LF, HF), and satellite observation of ionospheric turbulence and of VLF/LF transmitter signals. By showing these latest results and the corresponding theoretical interpretations of the above topics, it can be understood that the seismic precursory signature appears not only in the lithosphere, but also in the atmosphere and ionosphere. It is impossible to cover all the publications in this short review, so readers can consult the recent monographs by Pulinets and Boyarchuk [40], mainly on seismo-ionospheric effects, and by Varotsos [41], on lithospheric dc electric signals. We also remind the reader that very recent papers on SERP were collected as a special issue in *Physics and Chemistry of the Earth* [42].

It is evident that a combination of geophysics and radio physics leads to enrichment of research by new methods, ideas, and data-processing techniques.

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Sources for Dispersive Shear Alfvén Waves in the Magnetosphere: A Review

C.C. Chaston

Abstract

Recent observations from a number of spacecraft studying the plasmas of the Earth's magnetosphere have verified the importance of Alfvén waves, with small scales transverse to the geomagnetic field, in charged-particle acceleration. For instance, it has been shown that these waves drive intense aurora and ion outflow from the auroral oval, and may be important in plasma transport at the magnetopause. These waves have generally been termed dispersive shear Alfvén waves. Most notably, they have been discussed in the inertial or kinetic limits, where corrections to magnetohydrodynamic shear Alfvén-wave dispersion due to electron mass or finite temperature become important. However, while these waves have been identified throughout the magnetosphere, their sources or the processes through which they are generated have not been clearly identified from observations. We discuss the means by which these waves may be generated in this review. We show statistical and case-study examples from the FAST and Cluster spacecraft, demonstrating that reconnection and mode conversion from surface Alfvén waves on the magnetopause provide two important source mechanisms for these waves.

1. Introduction

Shear Alfvén waves are inherently unstable with regard to decaying to smaller transverse scales [1]. This process may occur linearly, through mode conversion and phase mixing on transverse Alfvén speed gradients, or through reflection on conductivity gradients in the ionosphere; or nonlinearly, through a variety of instabilities. As a result, shear Alfvén waves observed in space invariably occur with multiple scales, and may exhibit spectral forms consistent with the operation of a turbulent cascade. Particle acceleration, and thus dissipation, occur when wave scales of the order of the characteristic plasma scales are reached. In space plasmas, these include the electron inertial length or electron skin depth (λ_e), the ion acoustic gyro-radius (ρ_s), and the ion gyro-radius (ρ_i). On these scales, shear Alfvén waves are generally described as dispersive shear Alfvén waves (or, from here on, as simply dispersive Alfvén waves), because their phase speed is dependent on their perpendicular scale or wavenumber. More specifically, if the electron thermal speed is greater than or less than the Alfvén speed, then these waves are called kinetic Alfvén waves or inertial Alfvén waves, respectively. For a complete description of the properties of these waves and the subtleties of the naming conventions for these wave modes, the interested reader can consult the seminal works and reviews in this area [2, 3].

Significantly, dispersive Alfvén waves can carry an electric field parallel to the geomagnetic field ($E_{||}$). This has at least two important consequences for the magnetosphere. Firstly, it constituents a breakdown of the frozen-in condition, and allows motion of the plasma across the magnetic field. Because Alfvén waves have extremely long parallel wavelengths, this decoupling means that these waves provide a means for mixing plasmas over large parallel scales, across classically impenetrable boundaries such the magnetopause. Consequently, anomalous plasma transport in Alfvén waves is a leading candidate to account for the formation of the low-latitude boundary layer [4]. Secondly, for magnetospheric plasmas, it is often found that the magnitude of the parallel potential drop given by the finite $E_{||}$ that these waves carry is sufficient to accelerate large fractions of observed electron distributions to speeds similar to the parallel wave phase speed, over time scales less than an Alfvén-wave period. Under these circumstances, large fluxes of electrons may become Landau resonant with

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the wave, leading to beams of electrons traveling with the wave along the geomagnetic field. For waves propagating toward the auroral oval, this process has been shown to be a significant means for driving aurora [5]. The currents carried by these waves may also lead to various instabilities, leading to ion heating through cyclotron resonance [6], or to stochastic scattering in the Alfvén-wave field, itself [7, 8]. Consequently, understanding the origin of these waves or how these waves are powered is important for understanding the magnetosphere and some of the most dramatic processes occurring within it. With this motivation, we now review some of the means by which these waves may be generated in the magnetosphere, and then present two case-study examples.

2. Source Processes for Dispersive Alfvén Waves

2.1 Mode Conversion

An often-cited but observationally under-studied process is the production of dispersive Alfvén waves via mode conversion from fast-mode or surface-mode Alfvén waves at the magnetopause [9, 10]. This has been suggested to occur on transverse density gradients at the magnetopause where the local Alfvén speed matches the phase speed of surface or fast-mode Alfvén waves, known to exist in these regions. Some observations [11, 12] have revealed variation from largely compressional magnetic fluctuations in the magnetosheath to a more-transverse character, with transition through the magnetopause. These waves have a broad spectrum of oscillations, from 10s to 100s of mHz in the spacecraft frame. These data have more recently been reexamined [10] to show that the observations are consistent with mode conversion from fast-mode Alfvén waves in the magnetosheath to kinetic Alfvén waves across the magnetopause. The dependency on the angle between the background magnetic field in the magnetosheath, to that in the magnetosphere, was stressed in this study to show that efficient conversion occurs for angles larger than 50°. At smaller shear angles, mode conversion from surface Alfvén waves may be more important [9], particularly on the dawn and dusk flanks. where the Kelvin-Helmholtz instability is likely to excite large-amplitude surface-mode waves. In fact, recent observations have provided compelling evidence for the operation of the Kelvin-Helmholtz instability here [13]. The nonlinear phase of this instability produces waves over a broad spectrum of scales, capable of mode converting to kinetic Alfvén waves on the enhanced density gradients in “rolled-up” vortices across the magnetopause. Similar mode-conversion processes have been invoked to account for kinetic Alfvén waves observed in the plasma-sheet boundary layer [5], where transverse Alfvén speed gradients are known to exist. The efficacy of such a process has been demonstrated from simulations in this region [14]. However, despite the circumstantial and simulation evidence that these mode-conversion processes should occur, there have been very few observation-based studies using in-situ data to confirm their operation.

2.2 Reconnection

Reconnection is also a potential source for dispersive Alfvén waves. Kinetic simulations of the reconnection process suggest that it may be possible to generate waves at kinetic and electron inertial scales in the diffusion region. These simulations have emphasized the importance of non-ideal MHD terms in the generalized Ohm’s law, including the Hall term and those associated with electron inertia and electron pressure [15]. Electrons in the diffusion region decouple from the magnetic field to form a current layer with a width of the order of λ_e. Current sheets on these scales are unstable to a tearing instability, which, in low-beta plasmas, has been shown to radiate inertial Alfvén waves [16, 17]. When a significant component of the magnetic field perpendicular to the plane of the X line is included, the ions decouple from the magnetic field to provide ion current layers with widths of the order of ρ_s, thereby providing a source for kinetic Alfvén waves. The role of kinetic Alfvén dynamics in reconnection was explained in a review paper [18]. In both the inertial and kinetic case, strong Alfvénic turbulence develops. For instance, it has been has suggested [19] that the resistivity due to Alfvén waves radiated by these small-scale current structures could mediate the magnetic-tearing process. Indeed, in an unpublished survey of a number of events by the author, it has been found that these waves are invariably present in reconnection jets and across the diffusion region when traversed.

2.3 Phase Mixing and Self Interaction

Structuring of shear Alfvén-wave fields on transverse gradients in the Alfvén speed provides a simple and perhaps pervasive means by which shear Alfvén waves may become dispersive, and has long been discussed as phase mixing in the context of field-line resonances. It is probable that such a process occurs wherever appreciable transverse gradients exist along fields on which shear Alfvén waves propagate. Simulations of the phase-mixing process [20-22] have show that scales less than an electron inertial length can be attained very rapidly by this means. For a propagating shear Alfvén wave, such a process may occur continually along a field line from its source, which may be deep in the magnetotail or at the magnetopause. Once scales of the order of the electron inertial length have been attained, it has been shown by several authors that finite-amplitude effects in shear Alfvén waves can lead to the production of smaller-scale waves [16] through current instabilities or local shear instabilities in the Alfvén-wave field [23]. Filamentation instabilities [24] may also be effective for Alfvén waves on gyro-radii scales, and may produce a cascade to yet smaller scales. The results of this structuring are evident in observations that show electron and ion acceleration in these waves along field lines stretching from the ionosphere to the magnetopause. However, these processes do not describe the means by which dispersive Alfvén waves are powered, but rather may account for the transfer of wave energy from large to small scales. Because shear Alfvén waves are invariably observed over a broad spectrum, such processes may be continually active in shear Alfvén waves along geomagnetic field lines.

2.4 Velocity Space Instabilities

Dispersive shear Alfvén waves may also be unstable to ion and electron beams, such as those that populate the plasma-sheet boundary layer. It has been argued from observations from the Polar and Geotail spacecraft that reconnection flows are unstable to Alfvén waves, and can experience "braking" due to the emission of Alfvén waves [25]. This process was suggested to account for a lack of observations of near-Earth reconnection flows, and to drive wave Poynting flux into the auroral oval. Plasma instabilities – such as the current-driven kink instability [26], and the ion-beam-driven magnetosonic and ion-cyclotron instabilities associated with anisotropic ion flows at speeds of the order of the local Alfvén speed – have been demonstrated [27] to grow to levels sufficient to account for the amplitude of the observations [5], and of earlier observations of waves of this kind in the plasma-sheet boundary layer [28]. Quasi-linear simulations [29] have shown how these waves can provide electron acceleration to yield electron-velocity moments of the order of half the local Alfvén speed, and can account for the observed wave spectra observed from the ISEE spacecraft in these regions. However, these instabilities are most effective at generating waves that propagate parallel to the geomagnetic field with small $k_\perp / k_\parallel$ ratios, as distinct from the dispersive Alfvén waves, which propagate obliquely to the geomagnetic field. The required perpendicular structuring may however be produced after these waves are generated by the refraction of the wavefront in the increasing magnetic field as it propagates Earthward, and by phase mixing or oblique current and shear instabilities of the kind discussed in Section 2.3.

2.5 Ionospheric Feedback

At altitudes below ~1 Re, the ionospheric feedback instability [30] has been shown theoretically [31, 32] and from observations [33] to produce shear Alfvén waves on dispersive scales. It may also be responsible for the generation of fine structuring of field-line resonances. In this process, ionospheric conductivity variations due to electron precipitation cause changes in the local convective ionospheric fields and drive currents that launch Alfvén waves. Multiple reflections of the launched wave from a second boundary – given either by the non-conducting gradient in V_A at ~ 1 Re [30] or the conducting ionosphere in the conjugate hemisphere [34] – can lead to constructive reinforcement with each cycle, and thereby provide wave growth in the cavity between these boundaries. This process has been shown to promote the production of small scales. It has been found in simulations that a height-integrated Pedersen conductivity of $\Sigma_p \sim 1/(\mu_0 V_{AI})$ is an optimum condition for the production of small-scale currents from the unstable feedback response of the ionosphere in this manner, where V_{AI} is the Alfvén speed just above the ionosphere [32]. This instability may occur for wavenumbers satisfying [31] $\gamma k_\perp \bullet V_d / (V_{AI}/h) > 2.4$, where γ is the number of electron-ion pairs produced per incident electron in the field-aligned wave current or accelerated by the wave, V_d is the relative horizontal drift between ion and electrons (Hall and Pedersen currents), and h is the ionospheric scale height. As this threshold condition suggests, the growth rate of the instability increases with $k_\perp$, and may become strongly nonlinear at small scales, leading to intense highly localized currents [31] (i.e., larger $k_\perp$). The smallest scales that this instability can produce are limited by dissipative processes that become operable at scales of the order of λ_e, ρ_i, and ρ_s due to kinetic effects, and ultimately by the resistivity of the ionosphere to waves with parallel scales of the order of an ionospheric scale height. As indicated above, at scales of this order, the wave fields are unstable to oblique current and shear instabilities discussed in Section 2.3, which may give rise to the turbulent fields often observed above the auroral ionosphere [35].

3. Source Regions

It is likely that phase mixing and various instabilities are nearly always at work in generating the broad *k* spectra of Alfvénic fluctuations observed in the magnetosphere, and that ionospheric feedback plays an important role at low altitudes. However, reconnection and mode conversion at the magnetopause and in the magnetotail provide a physical mechanism through which these processes may be driven. Indeed, the importance of these processes for

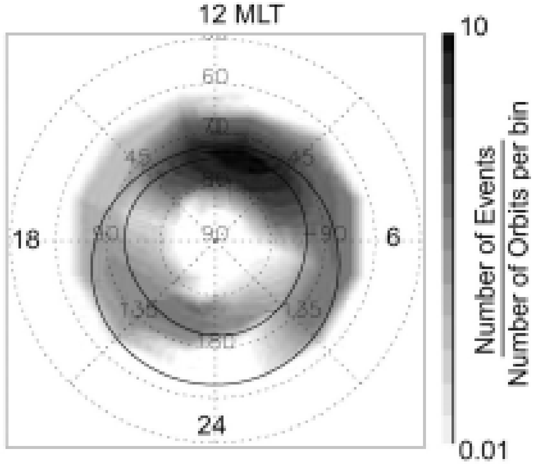

Figure 1. The distribution of dispersive Alfvén waves observed from the FAST satellite from an altitude of 350-4120 km. The dashed contours show invariant latitude, while the solid lines are the boundaries of a statistical model (Feldstein) for the auroral oval.

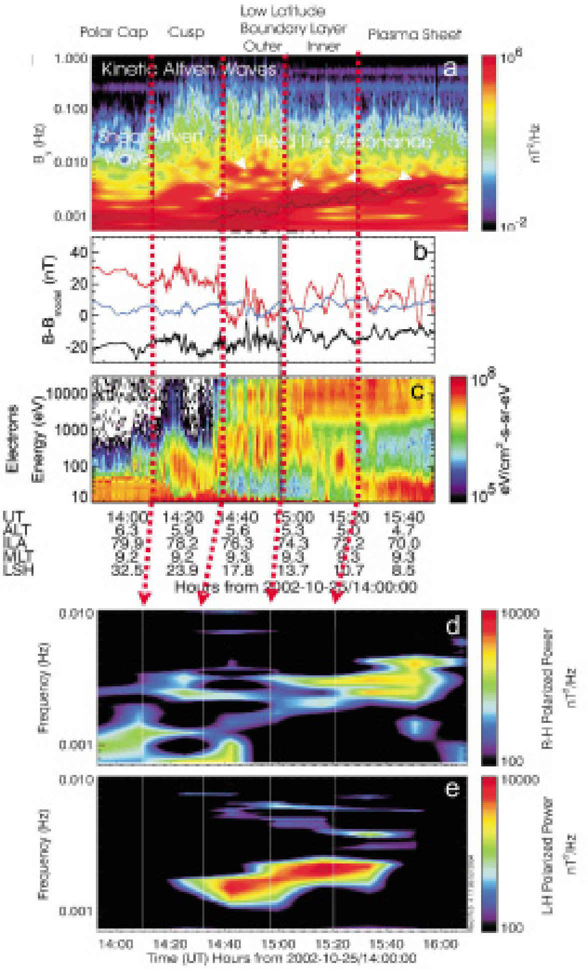

Figure 2. A mode-conversion case study. a) The magnetic-field wave spectrogram of azimuthal (toroidal) magnetic-field fluctuations. b) The magnetic-field time series. Black is the radial or poloidal component (x), red is the azimuthal or toroidal component (y), and blue is the geomagnetic field-aligned (z) component. c) The electron energy spectrogram. d) The R-H polarized wave power below 4 mHz. e) The L-H polarized wave power below 4 mHz.

powering dispersive Alfvén waves in the magnetosphere is suggested by their spatial distribution at high latitudes, which we now discuss.

Since dispersive Alfvén waves have group speeds aligned largely along the geomagnetic field, a simple means to determine which field lines contain the source for these waves is to identify the field lines on which they are observed by low-altitude spacecraft. In one study, the distribution of small-scale Alfvén waves observed above the auroral oval for all MLTs [magnetic local times] was determined from FAST observations [36]. This distribution is shown in Figure 1, and indicates a peak in the occurrence of these waves close to noon, and extending presumably through the cusp and the low-latitude edge of the polar cap, indicated by the inner edge of the Feldstein auroral oval (the inner black circle). There exists a bias toward the morning sector. Similar distributions have been identified from the Orsted satellite [37] for small-scale field-aligned currents. A secondary, albeit weaker, peak in occurrence rates can be identified pre-midnight on the open/closed field-line boundary, indicated here by the inner edge of Feldstein auroral oval, as also found from Polar observations [38]. This distribution suggests an association between these waves observed at low altitude and processes occurring along field lines that map to the sub-solar magnetopause, and field lines just tail-ward of cusp, where reconnection may occur for southward or northward orientations of the IMF [interplanetary magnetic field], respectively. It is also consistent with processes occurring tail-ward of the sub-solar point on the flanks of the magnetosphere, due, for instance, to the mode conversion of surface Alfvén waves and the Kelvin-Helmholtz instability. The peak in nightside observations maps to the plasma-sheet boundary layer, and along the separatrix between open and closed field lines in the magnetotail. Kinetic Alfvén waves in these regions have been well documented with observations by the Polar satellite [5, 38] and, most recently, from the Cluster spacecraft [39]. The location of these waves on the separatrix naturally suggests an association with reconnection in the magnetotail, while the transverse density gradients characteristic of these regions suggests that mode conversion may also have a role to play in driving the spectrum of shear Alfvén waves observed here.

These observations show that dispersive Alfvén waves occur on the open-closed field-line boundaries. These field lines extend outwards from the topside ionosphere into the high-altitude cusp on the dayside, and to the plasma-sheet boundary layer on the nightside. Using two case-study examples from the Cluster spacecraft, we now demonstrate that mode conversion [40] and reconnection [41] occurring on these boundaries do indeed provide a means for powering the broad *k* spectra of shear Alfvén waves observed.

4. Mode Conversion as a Driver of Dispersive Alfvén Waves

Figure 2 shows observations from the Cluster-1 spacecraft at an altitude of 6 Re above the dayside auroral oval, while traversing field lines spanning the polar cap, cusp, low-latitude boundary layer (LLBL), and plasma sheet. Each region has been identified from an inspection of the particle data recorded by the spacecraft over this interval. Figures 2a and 2b show that through the cusp and low-latitude boundary layer, a broad spectrum of magnetic fluctuations was observed, giving way to narrower-band oscillations at frequencies below 4 mHz, with entry onto the closed field lines of the inner low-latitude boundary layer and plasma sheet. The nature of these oscillations is indicated on the spectral results of the azimuthal magnetic-field oscillations shown in Figure 2a. Here, each mode has been identified from a consideration of wave polarization and the effects of spacecraft Doppler shift, as we will now describe. The black line superimposed on the peak of the spectra in Figure 2a is the toroidal-mode shear Alfvén wave

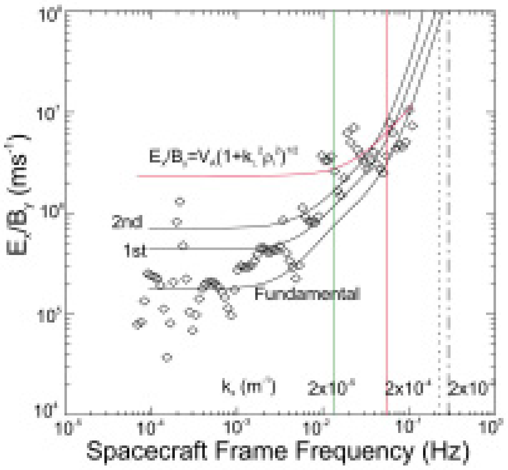

Figure 3. E_x / B_y *at Cluster-1: the red curve shows the kinetic Alfvén wave dispersion based on local parameters at Cluster-1, while the black curves show the wave dispersion in the non-local case for the fundamental and harmonic eigenmodes. The* k_x *values given were calculated with an average spacecraft speed of 3.13 km/s. For all panels, the green vertical line shows the Doppler shift in the spacecraft frame for stationary structures with a size equal to the gyro-radius in the equatorial plane mapped to the altitude of Cluster-1. The red line, dotted line, and dot-dashed line show the Doppler shift for the local ion gyro-radius (* ρ_i *), ion acoustic gyro-radius (* ρ_s *), and the electron inertial length (* λ_e *), respectively, at Cluster-1.*

eigenfrequency of the field line on which the waves are found. This frequency has been determined from the solution of an eigenmode equation [42, 43] for the observed parameters in a dipole-field geometry [40]. The correlation between the spectral peak and the eigenfrequency indicates that from the inner low-latitude boundary layer and extending into the plasma sheet, the lowest-frequency oscillations are toroidal-mode field-line resonances [44]. Figures 2d and 2e show the wave-polarization state of these oscillations. The reversal in polarization from left-handed to right-handed at ~2 mHz in the inner low-latitude boundary layer is a "smoking gun" for the resonant mode-conversion process from surface Alfvén waves on the morningside flanks of the magnetosphere to shear waves along the open/closed field-line boundary. At higher frequencies, in the spacecraft frame, the wave mode is identified by a consideration of the transverse-electric-to-magnetic-field ratio and $k_\perp$, derived from spacecraft Doppler shift, as shown in Figure 3. The diamonds here show the data, while the black lines show the solution of an eigenmode equation for shear Alfvén waves including kinetic effects. The agreement found provides strong evidence that these higher-frequency oscillations are dispersive Alfvén waves with $k_\perp \rho_i$ of order one. These waves are typically identified as kinetic Alfvén waves. The continuity of the k spectra – in this case, from non-dispersive scales, where E_x / B_y is that expected from an MHD eigenmode, through to highly dispersive scales, where E_x / B_y becomes increasingly electrostatic, consistent with kinetic Alfvén-wave dispersion – shows that the mode-conversion process drives a broad spectrum of dispersive Alfvén waves.

5. Reconnection at the Magnetopause as a Driver of Dispersive Alfvén Waves

Figure 3 shows observations at the magnetopause [41] from the Cluster-3 spacecraft during a period of northward interplanetary magnetic field. This is a reconnection event identified in a previous study [45], and the schematic presented in Figure 4a follows from this work. The Cluster spacecraft passed firstly from the lobes into a tailward-directed reconnection jet, and through a diffusion region, before passing into an Earthward-directed reconnection jet and then into the magnetosheath shown by the enhanced ion fluxes in Figure 4b. Figure 4c shows the existence of strong flows and, significantly, a reversal of the

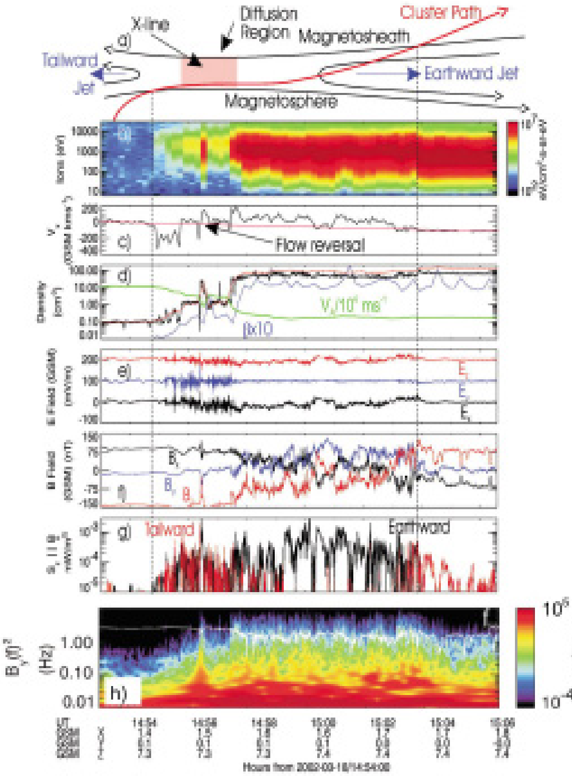

Figure 4. A reconnection case study. a) A schematic diagram of X-line crossing. b) The ion energy spectra. c) The sunward ion flow. d) The density (black, red), Alfvén speed (green), and β *(blue). e) The electric field in GSM coordinates. f) The magnetic field in GSM coordinates. g) The field-aligned Poynting flux. h) The transverse magnetic-field spectra.*

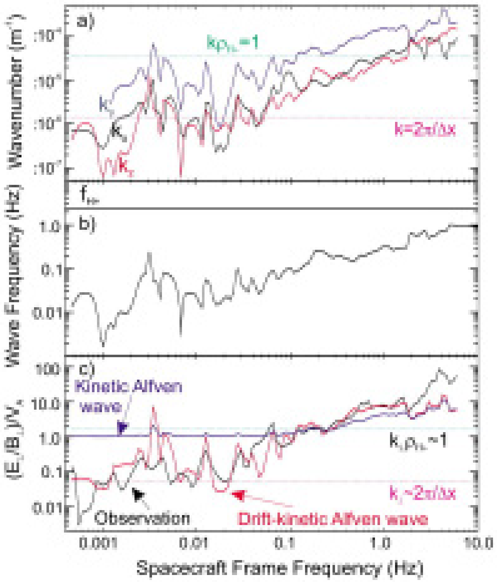

Figure 5. The averaged results from 14:55-14:56:30 UT: a) The wave vector from interferometry in field-aligned coordinates as defined in the text; b) The wave frequency for the drift-kinetic wave from solution of drift-kinetic Alfvén-wave dispersion; c) The observed E_x/B_y ratio (black), the predicted result from homogeneous theory (blue), and the predicted result for the drift-kinetic Alfvén wave (red).

flow direction, indicating the location of the X line. Figure 3d shows the presence of a strong density gradient, representing the outer edge of the magnetopause, where magnetosheath plasma diffuses into the magnetosphere. Figures 3e and 3f show that the electromagnetic fluctuations are largely constrained to the region where strong flows are observed. And, most importantly, Figure 3g shows that there is a reversal of the wave Poynting flux across the X line. This observation suggests that the reconnection occurring across the boundary [45] is the source for these fluctuations.

Similar to those observations discussed in Section 4, Figure 4h shows that the wave spectra in B (and E) observed through the traversal of the X line is featureless as a function of frequency in the spacecraft frame, with no clear spectral peaks apparent. Fortuitously, in this case the spacecraft were sufficiently closely spaced that interferometry could be applied to identify the wave vector of these oscillations and, hence, the wave mode. Figure 5 shows the results from this analysis, applied over the interval from 14:54-14:56:30 UT, where the strong density gradient was identified. (The interested reader can find more details in the manuscript [41] from which this figure was taken). In Figure 5a, we show the wave vector in a field-aligned coordinate system, while Figure 5b shows the wave frequency determined from the observed wave vector, and the solution to the dispersion relation for drift-kinetic Alfvén waves on the observed density gradient. Figure 5c provides a comparison of the expected transverse-wave-field ratio E_x/B_y for drift kinetic Alfvén waves (red) with the observed result (black). Drift kinetic Alfvén waves are kinetic Alfvén waves the dispersion of which is modified by coupling to drift modes on spatial plasma gradients [46]. Excellent agreement was obtained over nearly the whole frequency range observed, thereby providing convincing evidence that these waves are drift-kinetic Alfvén waves. A similar analysis (not shown) indicated that the waves observed in the Earthward reconnection jet from 14:58-15:03 UT are kinetic Alfvén waves. These measurements identify dispersive Alfvén waves streaming outwards from a reconnection X line at the magnetopause, and so indicate that reconnection is a source for these waves in the magnetosphere.

6. Concluding Remarks

In this report, we have reviewed the means by which dispersive Alfvén waves may be generated in the magnetosphere. The two case-study examples shown demonstrate that mode conversion and reconnection are source mechanisms for dispersive shear Alfvén waves in this region of near-Earth space. These mechanisms provide a means whereby the magnetic and kinetic energy present in the solar wind may drive processes occurring in the magnetosphere and ionosphere, facilitated by energy transport in shear Alfvén waves. This energy may then be dissipated in dispersive shear Alfvén waves as the end result of a cascade from magnetohydrodynamic to kinetic scales. This cascade may be facilitated by the various instabilities discussed in Section 2 of this report, powered by reconnection and mode conversion at the magnetopause. While not shown here, similar examples [47] can be used to demonstrate that the same processes are active across plasma boundaries inside the magnetotail.

7. Acknowledgements

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Ultra-Wideband Wireless Systems: A Broad Overview

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Abstract

In recent years, the research and development of ultra-wideband (UWB) wireless systems for communication, localization, and sensing have widely emerged. Nowadays, UWB has become a promising technology for high- and low-data-rate wireless communications and accurate positioning, with a focus on indoor environments. Driven by the efficient utilization of the electromagnetic spectrum, UWB serves as an overlay approach, and covers an unlicensed and enormously wide frequency band of several gigahertz. The aim of this contribution is twofold: first, to give a broad overview of UWB systems, and second, to illustrate a general framework for modulation schemes and deterministic MIMO (multiple-input multiple-output) channel models. Further attention is devoted to pulse shaping, antennas and propagation, multi-band OFDM (orthogonal frequency-division multiplexing), and localization systems.

1. Regulation

In April 2002, the US Federal Communications Commission (FCC) released the first report and order regarding the application of UWB communication devices. The FCC opened the spectrum from 3.1 GHz to 10.6 GHz – a bandwidth of 7.5 GHz – for unlicensed use, with up to -41.3 dBm/MHz [1] for indoor UWB systems. The emission limits set by the FCC mask are shown in Figure 1.

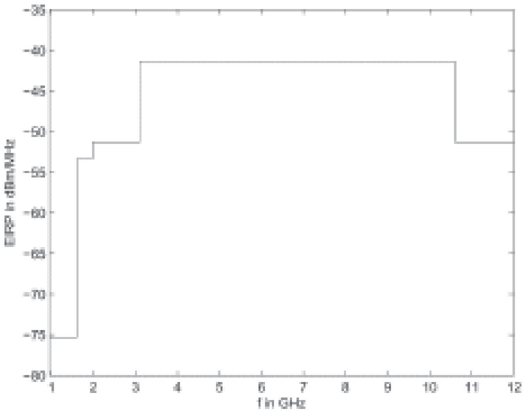

Figure 1. The FCC mask

2. Pulse Shaping

In IR-UWB (impulse radio ultra-wideband) systems, pulses are used to transmit data over a wireless channel. The pulse shape is of particular relevance for several reasons. First, the pulse should fit the regulated emission mask for UWB systems, in order to use as much energy for transmission as possible. Possible pulse-design strategies to adapt the pulse shape to a given frequency behavior are given in [1]. Roughly, the pulse length, T_P, determines the occupied bandwidth, and the pulse repetition time determines

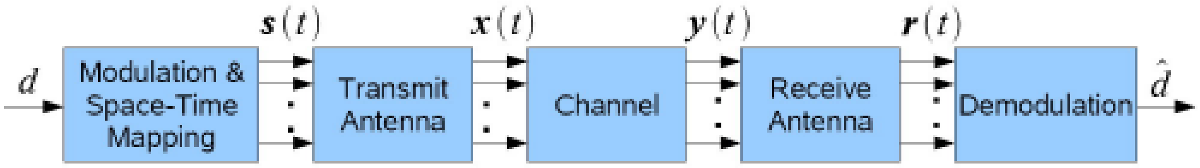

Figure 2. A transceiver.

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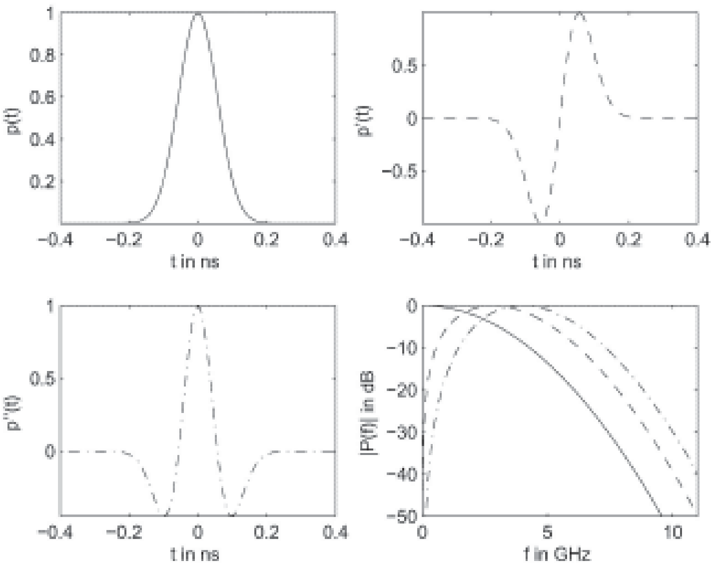

Figure 3. Gaussian pulses with $\tau_p = 0.2$ ns.

the center frequency. Because of its easy mathematical tractability, the most often-used conventional pulse shapes are the Gaussian pulse and its derivatives:

$$p_G(t) = e^{-2\pi\left(\frac{t}{\tau_p}\right)^2}, \tag{1a}$$

$$p_{G^{[n]}}(t) = A_n \frac{d}{dt^n} p_G(t), \quad n \in \{1, 2, \ldots\}, \tag{1b}$$

where τ_p is a parameter controlling the pulse length, T_P (or, in other words, τ_p is a parameter controlling the bandwidth); and A_n designates the quantity that enables $p_{G^{[n]}}(t)$ to satisfy the unit-power normalization. In a particular experimental radio link [2], the value $\tau_p = 0.7531$ was used to fit the model $p_G(t)$ from a measured waveform. As seen in [3-7], for example, the second-order derivative Gaussian monocycle is the most widely reported pulse, given by

$$p_{G^{[2]}}(t) = \left[1 - 4\pi\left(\frac{t}{\tau_p}\right)^2\right] \mathrm{e}^{-2\pi\left(\frac{t}{\tau_p}\right)^2}. \tag{2}$$

Its normalized autocorrelation function, $r_{pp}(\tau)$, is shown as [8]

$$r_{pp}(\tau) = \frac{1}{\int_{-\infty}^{\infty} p_{G^{[2]}}^2(t)\,\mathrm{d}t} \int_{-\infty}^{\infty} p_{G^{[2]}}(t)\, p_{G^{[2]}}(t+\tau)\,\mathrm{d}t$$

$$= \left[1 - 4\pi\left(\frac{\tau}{\tau_p}\right)^2 + \frac{4}{3}\pi^2\left(\frac{\tau}{\tau_p}\right)^4\right] e^{-\pi\left(\frac{\tau}{\tau_p}\right)^2}. \tag{3}$$

The Gaussian pulse, the first and second derivatives, and the frequency behavior of the pulses are shown in Figure 3. Each differentiation causes an additional zero crossing, and in the frequency domain it can be noticed that the higher the order of differentiation, the higher the center frequency. Other pulse shapes are listed in [13]. In addition, a set of orthogonal pulse forms [14] can be designed to distinguish different users, i.e., to handle a multi-user system under idealistic channel conditions. However, in the real world, at least the transmitted pulse is not equal to the generated pulse.

3. Generic IR-UWB Modulation Schemes

Various approaches for impulse-radio UWB systems have been developed depending on different spreading codes, e.g., time-hopping (TH) UWB [9], direct-sequence (DS) UWB [10], or baseband single-carrier/multi-carrier UWB [11]. However, the most well-known and classical UWB waveform for short-range wireless communication is based on time-hopping impulse radio (TH-IR), which is explained in the following as a representative example.

In digital communication, in general the n_u th user needs to convert the desired information into a transmitted data symbol, $d_{n_U}[n]$. As a consequence, the prescribed user has to possess its own identity, so that multiple access takes place without any catastrophic collision. This can be accomplished by assigning a time-shift sequence, called the TH code, $c_{n_U}[n]$. Let T_C be the duration occupied by each TH code. Collecting all N_C chips into a frame [8], each frame will possess a time duration $T_F = N_C T_C + T_G$, where T_G is the guard interval between adjacent frames. This additional period is introduced to support processing delay at the receiver. For any n_F th frame, the TH code is thus permitted to be $c_{n_U}[n] \in \{0, 1, \ldots, N_C - 1\}$. Furthermore, each TH code consists of monocycle $p(t)$, with $T_P \ll T_C$. At the transmitter, the TH-UWB signal is expressed as (e.g., see [9, 14, 15])

Schemes	$a_{n_U}[n]$	$a_{n_U}[n]_{M=2}$	$b_{n_U}[n]$	$b_{n_U}[n]_{M=2}$	Etc.
PPM	1	1	$d_{n_U}[n]$	A: $\{0,1\}$ B: $\{-1,1\}$	[7] [14]
Orthogonal PPM	1	1	$d_{n_U}[n]$		$\delta = T_P$ [13]
Optimal PPM	1	1	$d_{n_U}[n]$		$\hat{\delta} = \arg\min_{\delta} r_{pp}(\delta)$
PAM	$2d_{n_U}[n]+1-M$	$\{-1,1\}$	0	0	[14], [15, eq. (13)]
BPSK	$2d_{n_U}[n]-1$	$\{-1,1\}$	0	0	[14]
OOK	$d_{n_U}[n]$	$\{0,1\}$	0	0	[14], [16]

Table 1. TH-IR UWB modulation schemes for M-ary information symbol [15, p. 31] $d_{n_U}[n] \in \{0,1,\ldots,M-1\}$

$$s_{n_U}\left(t_{n_U}\right) = \sqrt{\bar{E}_{n_U}} \sum_{n_F=-\infty}^{\infty} a_{n_U}\left[\left\lfloor \tfrac{n_F}{N_F} \right\rfloor\right]$$

$$p\left\{t_{n_U} - n_F T_F - c_{n_U}\left[n_F\right] T_C - b_{n_U}\left[\left\lfloor \tfrac{n_F}{N_F} \right\rfloor\right]\delta\right\}, \quad (4)$$

where t_{n_U} and $\bar{E}_{n_U}$ are the n_U th user's clock time and energy per pulse, $a_{n_U}[n]$ and $b_{n_U}[n]$ are data sequences corresponding to a modulation scheme in Table 1, and δ is the modulation index representing the time shift associated with binary PPM. In this paper, the operator $\lfloor \bullet \rfloor$ stands for rounding the elements of $\bullet$ to the nearest integer towards minus infinity. In addition, the pulse-amplitude modulation (PAM) in Table 2 is called time-hopping phase-shift keying (TH-PSK). In this point of view there is another modulation scheme that is very close to TH-PSK, called direct-sequence phase-shift keying (DS-PSK). DS-PSK can be represented as [10, 16 eq. (28)]

$$s_{n_U}\left(t_{n_U}\right) = \sqrt{\bar{E}_{n_U}} \sum_{n_F=-\infty}^{\infty} a_{n_U}\left[n_F\right]$$

$$\sum_{n_C=0}^{N_C-1} c_{n_U}\left[n_C\right] p\left(t_{n_U} - n_F T_F - n_C T_C\right), \quad (5)$$

where the direct sequence, $c_{n_U}\left[n_c\right]$, has a length of N_C, and its value is given by $c_{n_U}\left[n_c\right] \in \{-1,+1\}$. Using the same idea as employed in time hopping, the so-called optical orthogonal code PPM (OOC-PPM) can be discovered to be [16 eq. (16)]

$$s_{n_U}\left(t_{n_U}\right) = \sqrt{\bar{E}_{n_U}} \sum_{n_F=-\infty}^{\infty} \sum_{n_C=0}^{N_C-1} c_{n_U}\left[n_c\right]$$

$$p\left\{t_{n_U} - n_F T_F - n_c T_c - b_{n_U}\left[n_F\right]\delta\right\}. \quad (6)$$

3.1 Proposition 1

Proposition 1: In lieu of time hopping in Equation (4), we offer a generalized modulation for direct sequence as

$$s_{n_U}\left(t_{n_U}\right) = \sqrt{\bar{E}_{n_U}} \sum_{n_F=-\infty}^{\infty} a_{n_U}\left[\left\lfloor \tfrac{n_F}{N_C} \right\rfloor\right] c_{n_U}\left[n_C\right]$$

$$p\left\{t_{n_U} - n_F T_F - n_C T_C - b_{n_U}\left[n_F\right]\delta\right\}$$

$$= \sqrt{\bar{E}_{n_U}} \sum_{n_F=-\infty}^{\infty} a_{n_U}\left[\left\lfloor \tfrac{n_F}{N_C} \right\rfloor\right] c_{n_U}\left[\operatorname{mod}\left(n_F, N_C\right)\right]$$

$$p\left\{t_{n_U} - \left\lfloor \tfrac{n_F}{N_C} \right\rfloor T_F - \operatorname{mod}\left(n_F, N_C\right) T_C - b_{n_U}\left[\left\lfloor \tfrac{n_F}{N_C} \right\rfloor\right]\delta\right\}, (7)$$

Scheme	$a_{n_U}[n]$	$a_{n_U}[n]_{M=2}$	$b_{n_U}[n]$	$b_{n_U}[n]_{M=2}$	Etc.
OOC-PPM	1	1	$d_{n_U}[n]$	A: $\{0,1\}$ B: $\{-1,1\}$	[14, eq. (16)]
DS-PSK	$2d_{n_U}[n]+1-M$	$\{-1,1\}$	0	0	[2],[14, eq.(16)]

Table 2. DS-IR UWB modulation schemes for M-ary information symbol $d_{n_U}[n] \in \{0,1,\ldots,M-1\}$.

where $\mathrm{mod}(n_F, N_C)$ is the modulo function (the integer remainder of division) of n_F with respect to N_C. The parameters are then set up as in Table 2.

3.2 Remark 1

Remark 1: Based on the expressions of Equations (4) and (7), there is an additional generalized formula, written as [5, eq. (1)]

$$s_{n_U}\left(t_{n_U}\right) = \sqrt{\bar{E}_{n_U}} \sum_{n_F=-\infty}^{\infty} a_{n_U}\left[\left\lfloor \frac{n_F}{N_C} \right\rfloor\right] c_{n_U,\mathrm{DS}}\left[\mathrm{mod}\left(n_F, N_{\mathrm{DS}}\right)\right] p\left\{t_{n_U} - n_F T_F - c_{n_U,\mathrm{TH}}\left[\mathrm{mod}\left(n_F, N_{\mathrm{TH}}\right)\right] T_C\right\}, \quad (8)$$

where N_{DS} and N_{TH} are the code lengths for direct sequence and time hopping, respectively. Note that the expression of Equation (8) is without transmission of the information in time hopping. In [17], it was shown that BPSK is suitable for high power efficiency and smooth spectrum; OOK for simple transceiver structure; M-ary PPM for improved power efficiency; and M-ary PAM for higher data rates.

In typical spread-spectrum communication, each frame is usually comprised of multiple symbols in order to convey the desired information. However, in a UWB system each symbol is constituted from a large number (N_F) of pulses, each of frame duration $T_F \gg T_P$. One can then see that the UWB system is thus contrary to most spread-spectrum communication systems, because a single symbol is spread over N_F frames. It is worthwhile to further note that the UWB system conveys $\log_2 M$ message bits from the M-ary modulation. In data-symbol interval $T_S = N_F T_F$, the bit rate provided by the UWB system therefore becomes $\frac{1}{T_S} \log_2 M$.

3.3 Frame-Level Representation

Let us consider the instant of the n_Sth data symbol. From an asynchronous point of view [18], the n_Uth user's signal transmitting the n_Sth data symbol, denoted by $s_{n_S,n_U}(t)$, can be written as (e.g., see [19] and [20])

$$s_{n_S,n_U}(t) = \sqrt{\frac{E_{n_U}}{N_F}} \sum_{n_F=n_S N_F}^{(n_S+1)N_F-1} a_{n_U}[n_S] \, p\left\{t - n_F T_F - b_{n_U}[n_S]\delta\right\}, \quad (9)$$

where E_{n_U} is the bit energy due to all frames.

3.4 Symbol-Level Representation

Let Δ be the gap between adjacent data symbols. Assume that the impulsion associated with a transmitted data symbol remains inside the current chip. Neglecting the user index and symbol energy, the UWB signal due to multiple symbols, denoted by $s(t)$, is represented as (e.g., see [21] and [22])

$$s(t) = \sum_{n_S=0}^{N_S-1} \sum_{n_F=0}^{N_F-1} a[n_S] \, p\left\{t - (n_S N_F + n_F) T_F - c[n_F] T_C - b[n_S]\delta\right\}, \quad (10)$$

where N_S is the number of data symbols in which channel statistics will still be invariant.

3.5 Channel Model

For the N_Uth user along the n_Pth path, the philosophy of modeling the UWB channel is to capture the channel amplitude, $\alpha_{n_P,n_U} \in \mathbb{R}$, and the path delay, $\tau_{n_P,n_U} \in \mathbb{R}$, into a parametric framework. Note that the antenna characteristics are usually not included in such conventional channel models (see also the next section). In vector notation, the n_Uth user's parameters can be written as $\mathbf{d}_{n_U} \in \mathbb{R}^{N_S \times 1}$, $\boldsymbol{\alpha}_{n_U} \in \mathbb{R}^{N_P \times 1}$, and $\boldsymbol{\tau}_{n_U} \in \mathbb{R}^{N_P \times 1}$:

$$\mathbf{d}_{n_U} = \left[d_{1,n_U} \quad d_{2,n_U} \quad \cdots \quad d_{N_S,n_U}\right]^T, \quad (11a)$$

$$\boldsymbol{\alpha}_{n_U} = \left[\alpha_{1,n_U} \quad \alpha_{2,n_U} \quad \cdots \quad \alpha_{N_S,n_U}\right]^T, \quad (11b)$$

$$\boldsymbol{\tau}_{n_U} = \left[\tau_{1,n_U} \quad \tau_{2,n_U} \quad \cdots \quad \tau_{N_S,n_U}\right]^T, \quad (11c)$$

	CM1	CM2	CM3	CM4
Environment	LoS	NLoS	NLoS	NLoS
Distance TX-RX in m	0-4	0-4	4-10	–
τ_{rms} in ns	5	8	15	25

Table 3. Parameters CM1-CM4.

where N_P is the number of multipath components. Assume that the same number of multipath components holds for all users. Let $n(t) \in \mathbb{R}$ be the additive noise due to several imperfections at the receiver. The received signal, $y(t) \in \mathbb{R}$, can be expressed as [23]

$$r(t) = \sum_{n_U=1}^{N_U} \sum_{n_P=1}^{N_P} \alpha_{n_P,n_U} s_{n_U}\left(t - \tau_{n_P,n_U}\right) + n(t)$$

$$= \sum_{n_P=1}^{N_P} \alpha_{n_P,n_U} s_{n_U}\left(t - \tau_{n_P,n_U}\right) + \tilde{n}_{n_U}(t), \qquad (12)$$

where N_U is the number of active users. The noisy multiple-access interference (MAI) is defined as

$$\tilde{n}_{n_U}(t) = \sum_{\forall \tilde{n}_u \neq n_u} \sum_{n_P=1}^{N_P} \alpha_{n_P,n'_U} s_{n'_U}\left(t - \tau_{n_P,n'_P}\right) + n(t) \qquad (13)$$

For analytic simplicity, the MAI $\tilde{n}_{n_U}(t)$ is assumed to be a Gaussian process. For a more-realistic MAI model, see [24]. Note that the signal model in Equation (12) is a usual framework in signal detection and parameter estimation. For analysis of the performance of all above modulation schemes, see [16, 17, 19, 20, 25]. The next section is devoted to UWB channel modeling where more-realistic effects are taken into account.

4. The UWB Channel

The UWB indoor propagation channel is characterized by a huge number of multipath components, due to high-resolution propagation. Measurement campaigns have shown that the length of a typical UWB indoor impulse response is between 50-100 ns, and the root-mean-square (RMS) delay spread is between 5-40 ns [4; 5, pp. 81; 6, p. 136]. In order to investigate UWB systems, e.g., communication systems or localization systems, an appropriate channel model is needed. The models can be divided into two categories, deterministic and stochastic channel models, where both of these are suited for different areas of application. Note that deterministic models are site specific, whereas the stochastic models are not site specific. For localization purposes, deterministic models are the only approach for reliable performance evaluation. In contrast, for communication systems, the channel model should reflect the realistic small- and large-scale behavior of different classes of environments, so that a stochastic model is more useful here.

As conventional narrowband or wideband channel models are not a-priori valid for the UWB propagation channel, a new stochastic channel model is required. Hence, the IEEE 802.15.3a task group developed a UWB channel model that was derived from extensive measurement campaigns, and reflected properties of the channel such as the power delay profile (PDP) and the RMS delay spread [7, Section 8.2; 8]. This model is an extension of the Saleh-Valenzuela wideband tapped-delay-line model. The impulse response consists of L clusters and K rays in each cluster, such as

$$h(t) = \sum_{l=1}^{L} \sum_{k=1}^{K} \alpha_{k,l} \delta\left(t - \tau_{k,l}\right), \qquad (14)$$

where the amplitudes are log-normally distributed and the delays are exponentially distributed. Parameters specifying four different scenarios (CM1-CM4) were provided by the task group. Table 3 shows some typical characteristics of the different scenarios. Example impulse responses for models CM1 and CM3 are given in Figures 4 and 5, respectively.

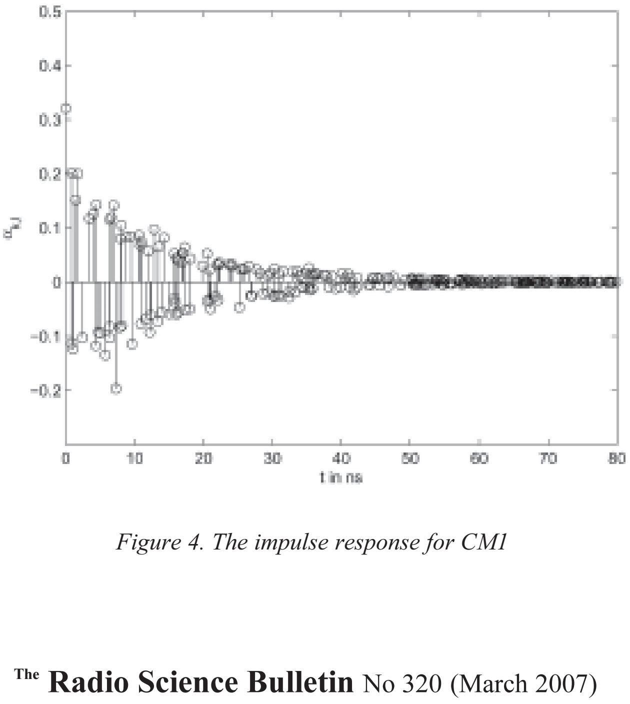

Figure 4. The impulse response for CM1

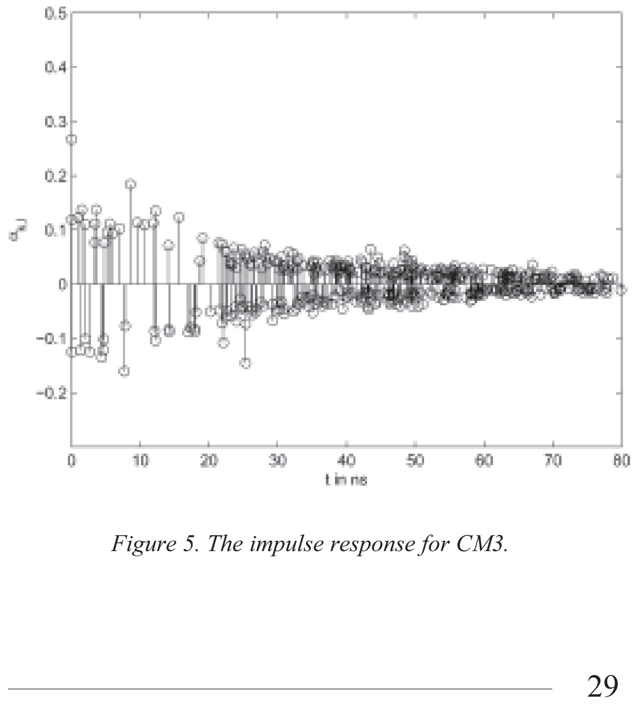

Figure 5. The impulse response for CM3.

Let us now turn to a deterministic type of channel model. First, note that because of the enormous spectral bandwidth, antenna parameters become strongly frequency dependent. This forces antenna engineers to define all of the electrical properties of the UWB antennas as functions of frequency. Therefore, in this contribution, the transmitting and receiving antennas will both be described by their angle-dependent impulse responses (or transfer functions), which can be either theta polarized, $h^{\theta}(t,\phi,\theta)$, or phi polarized, $h^{\phi}(t,\phi,\theta)$. Note that such a formulation can be seen as an extension of the classical and widely used directivity pattern, which only includes the magnitude of the spatial response, and not the frequency dependence.

The inclusion of the angular dependence is of particular relevance for any multiple antenna system (MAS), since a multiple antenna system exploits the spatial properties of the wireless channel. For instance, if both the transmitter and the receiver are equipped with multiple antennas – a so-called MIMO (multiple-input multiple-output) system – then a significant data rate improvement can be achieved. In the ideal case of N_T transmitting antennas and N_R receiving antennas, the ergodic channel capacity,

$$C_e = \min\left(N_T, N_R\right) B \log\left(1 + SNR\right), \qquad (15)$$

promises a distinctly higher data rate than a SISO (single-input single-output) system [26]. Note that B is the bandwidth of the channel, and *SNR* is the signal-to-noise ratio at the receiver. However, in order to exploit this gain, the spatial fingerprints (spatial signatures) among all transmitting antennas at the receiving antennas must be as different as possible, in order to successfully separate the N_T individual transmitted data streams at the receiver. Hence, a usual assumption is a *rich scattering environment*, which generally holds true in UWB indoor scenarios. However, in the case of a close distance between the transmitter and receiver, which is typical for highest data rate applications, the line-of-sight (LoS) path might dominate the communication channel, so that the desired impact of scatters is mitigated, to some extent.

Then, in terms of system parameters, the channel impulse response (CIR) between each pair of transmitting and receiving antennas in the system becomes approximately identical to the channel impulse response between every other pair. It is also evident that using identical omnidirectional antennas in both transmitting and receiving arrays, having the same radiation patterns and approximately the same positions, will also not support different spatial signatures.

It follows that for the *overall channel impulse response* (including the antennas), or the so-called effective channel impulse response (ECIR),

$$\mathbf{h}_{\mathrm{eff}}(t) = \int_0^{2\pi}\int_0^{2\pi}\int_0^{2\pi}\int_0^{2\pi} \mathbf{h}_T\left(t,\phi_T,\theta_T\right)$$

$$*\,\mathbf{h}_C\left(t,\phi_T,\theta_T,\phi_R,\theta_R\right) * \mathbf{h}_R\left(t,\phi_R,\theta_R\right) \mathrm{d}\phi_T \mathrm{d}\theta_T \mathrm{d}\phi_R \mathrm{d}\theta_R, \qquad (16)$$

where

$$\mathbf{h}_T\left(t,\phi_T,\theta_T\right) = \begin{bmatrix} h_T^{\theta}\left(t,\phi_T,\theta_T\right) & 0 \\ 0 & h_T^{\phi}\left(t,\phi_T,\theta_T\right) \end{bmatrix} \qquad (17)$$

and

$$\mathbf{h}_R\left(t,\phi_R,\theta_R\right) = \begin{bmatrix} h_R^{\theta}\left(t,\phi_R,\theta_R\right) & 0 \\ 0 & h_R^{\phi}\left(t,\phi_R,\theta_R\right) \end{bmatrix} \qquad (18)$$

are the matrices presenting the transmitting and receiving antenna impulse responses, respectively, considering theta and phi polarizations. In the mean term,

$$\mathbf{h}_C\left(t,\phi_T,\theta_T,\phi_R,\theta_R\right)$$

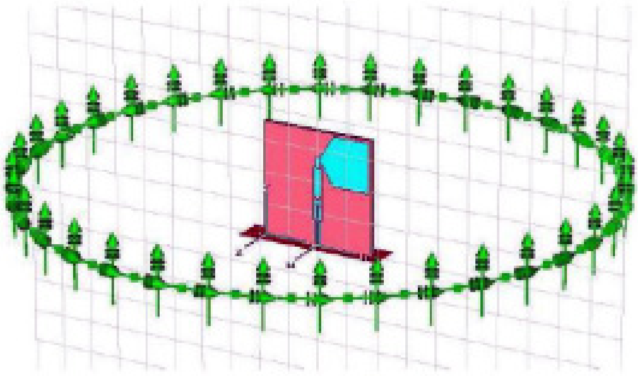

Figure 6. A typical bowtie antenna, surrounded by 36 probes oriented for theta polarization, and 36 probes oriented for phi polarization.

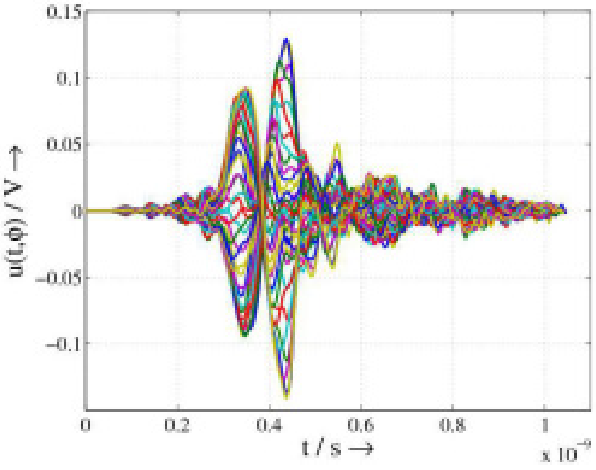

Figure 7. The antenna step response for the theta polarization.

$$= \begin{bmatrix} h_C^{\theta\theta}\left(t,\phi_T,\theta_T,\phi_R,\theta_R\right) & h_C^{\theta\phi}\left(t,\phi_T,\theta_T,\phi_R,\theta_R\right) \\ h_C^{\phi\theta}\left(t,\phi_T,\theta_T,\phi_R,\theta_R\right) & h_C^{\phi\phi}\left(t,\phi_T,\theta_T,\phi_R,\theta_R\right) \end{bmatrix} \qquad (19)$$

is the spatial channel between the transmitting and receiving antennas, considering the polarization types at both sides and excluding antenna effects. This rather complex description of the overall channel impulse response can be widely used. First, different types of antennas in the transmitting and/or receiving arrays can be investigated. Second, mutual coupling effects among the neighboring antennas are included. Third, the impact of polarization on the performance of a localization or communication system can be evaluated. In order to gain deeper insight and more quantitative results, some simulation results and details will be presented in the following.

As shown in Equation (2), the overall channel impulse response (CIR) can be mathematically divided into three major terms. These three terms are the transmitting-antenna impulse response, the spatial-channel impulse response, and the receiving-antenna impulse response.

The first term of the transmitting-antenna impulse response can be determined using an EM simulator, using a model of the antenna surrounded by several probes oriented for theta polarization, and further probes oriented for phi polarization. An example is given in Figures 6 and 7. The previously defined $h_C\left(t,\phi_T,\theta_T,\phi_R,\theta_R\right)$ can be determined and investigated for a selected environment by using a ray-tracing method.

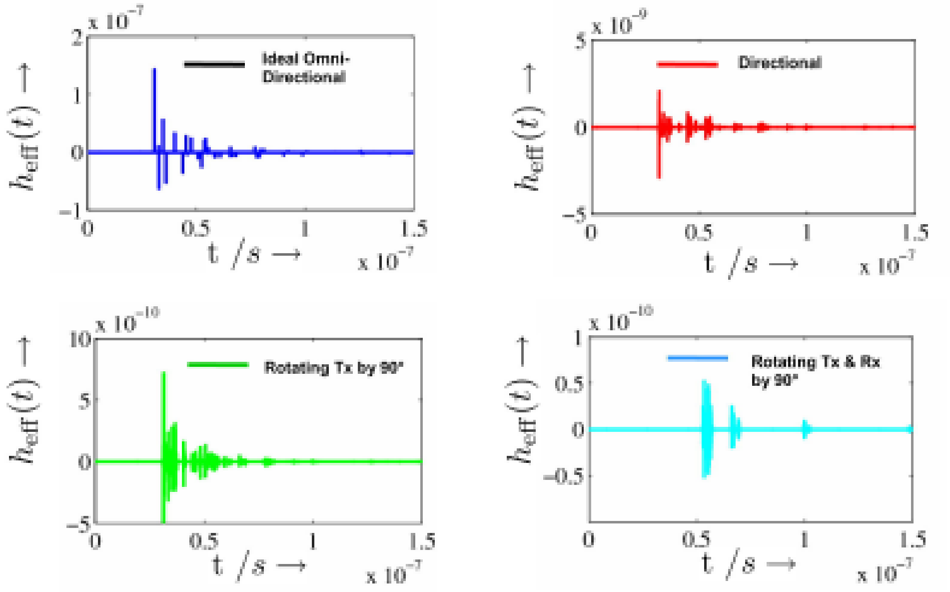

Fig. 8. The effective channel impulse response (ECIR) for a SISO system using (a) blue: ideal omnidirectional antennas; (b) red: typical directional UWB bowtie antennas; (c) green: typical directional UWB bowtie antennas, rotating the transmitting antenna by 90°; (d) cyan: typical directional UWB bowtie antennas, rotating both the transmitting and the receiving antennas by 90°.

Provided that the transmitting and receiving antennas are the same, the receiving-antenna impulse response can be determined by applying the theory of reciprocity, which provides the possibility of calculating the receiving-antenna impulse response from the transmitting-antenna impulse response via

$$\frac{\partial}{\partial t} h_R\left(t,\phi_T,\theta_T\right)=\frac{1}{2}c_0\int_{-\infty}^{\infty} h_T\left(\tau,\phi_T,\theta_T\right)\mathrm{d}\tau\,. \quad (20)$$

Figure 8 shows the overall channel impulse response obtained by the previous method for different antenna patterns. If the major transmitting lobe does not point toward the major receiving lobe, not only is the magnitude significantly reduced, but also the shape of each impulse response due to different multipath propagation.

Observe that the presented deterministic MIMO channel model is rather general and can be simplified to different special cases, e.g., SISO or single-polarized systems.

5. Multi-Band OFDM

In its evolution, the UWB technology has been split in two main streams: single-band, so-called impulse radio (IR); and multi-band (MB) UWB. Traditionally, UWB has been employed as carrier-free communications by directly modulating information into a sequence of very short pulses, occupying the available bandwidth of 7.5 GHz [27]. However, the single-band approach faces the challenge of designing a low-complexity receiver able to capture sufficient energy in multipath environments with strong fading. Moreover, building RF analog circuits that operate at GHz frequencies is rather demanding for state-of-the-art receiver front ends and analog circuits [28].

To circumvent these problems, multi-band UWB schemes have been recently proposed, in which the total 7.5 GHz bandwidth is divided into non-overlapping sub-bands of at least 500 MHz, in compliance with the FCC regulations. The advantage over single-band transmission is that by interleaving the symbols across different sub-bands, the information can be processed over a much smaller bandwidth. This allows for a reduction in the overall design complexity, a greater spectral flexibility, and worldwide compliance with present and emerging UWB technologies. Since a multi-band UWB system enables independent control of portions of the emitted spectrum, it can better cope with narrowband (NB) interference from existing services on adjacent frequency bands – e.g., IEEE 802.11a/b/g, DAB, DVB-T – and is therefore able to better comply with the UWB spectral mask posed by the FCC.

In multipath environments with rich scattering, the transmitted signal suffers deep fades in power level, resulting in loss of information at the receiver side. To circumvent the fading problem and efficiently capture the multipath energy, the orthogonal frequency-division multiplexing (OFDM) technique has been adopted in multi-band UWB to modulate the information onto each subband [29]. OFDM combats multipath by introducing a sufficiently long cyclic prefix (CP) at the beginning of each symbol, to convert the linear convolution with the channel impulse response into a circular convolution, and to ensure ideal detection by the FFT at the receiver. Along with being effective in exploiting the multipath components, OFDM can also provide a simple method for frequency-domain equalization, which is considered a significant problem for high-data-rate transmissions. The resulting transmission scheme, called MB-OFDM UWB, shares the well-proven advantages of any multi-carrier scheme. However, in contrast to traditional OFDM transmission where the symbols are continually sent on one and the same band, MB-OFDM systems apply frequency hopping, so that the symbols are interleaved over different subbands across both time and frequency. The carefully designed frequency-hopping sequences thus allow for multiple access of different users (or adjacent piconets), and for frequency-diversity gain in the system.

A UWB time-frequency-interleaved OFDM (TFI-OFDM) physical layer (PHY), proposed for IEEE 802.15.3a TG3a by Anuj Batra et al., employs fast frequency hopping of OFDM-modulated symbols across 528 MHz wide

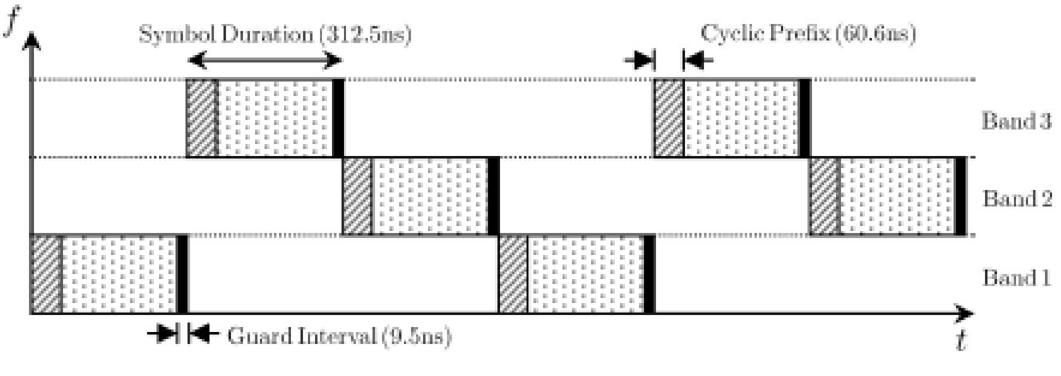

Figure 9. Time-frequency interleaving in MB-OFDM.

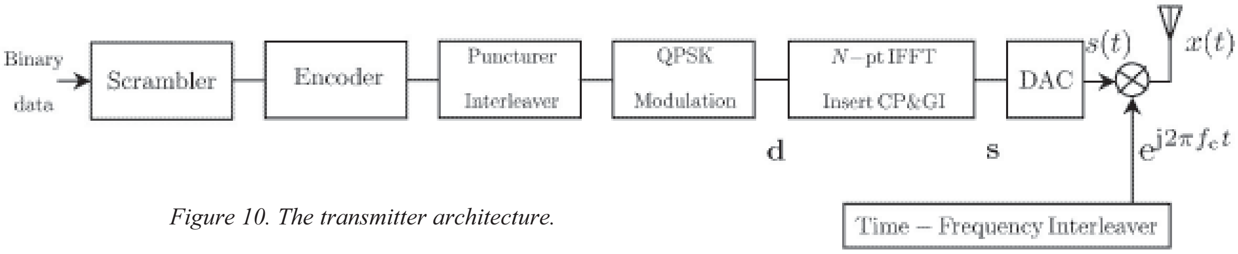

Figure 10. The transmitter architecture.

subbands [30]. In this system, the whole 7.5 GHz-wide UWB spectrum is subdivided into 14 subbands of 528 MHz bandwidth each, with three adjacent subbands being further combined into band groups (BG) 1-5. This enables multiple-user access and high-data-rate communication capabilities of from 55 up to 480 Mbps, depending on various puncturing patterns and spreading factors.

An example of how the data is transmitted across the different subbands using time-frequency interleaving is given in Figure 9. The whole MB-OFDM symbol consists of the actual user data, a cyclic prefix of length 60.6 ns, and a guard interval (GI) after each symbol to reduce the complexity of the receiver and to enable fast switching from the current subband to the next [31].

5.1 Transmitter Architecture

The transmitter architecture of the proposed MB-OFDM UWB system is quite similar to that of a traditional OFDM system. The main difference is the use of a time-frequency interleaver (TFI) to control the frequency hopping between subbands. Figure 10 shows the block diagram of an example transmitter architecture of the MB-OFDM UWB system. At the input of the system, payload binary data are first scrambled and then passed through an industry-standard convolutional encoder with generator polynomials $g_0 = 133_8$, $g_1 = 145_8$, and $g_2 = 175_8$. The different code rates (11/32, 1/2, 5/8, and 3/4) are derived from a 1/3-rate encoder by applying puncturing according to various patterns. By omitting certain bits at the transmitter side ("bit-stealing") and subsequent insertion of dummy zeros at the receiver decoder, the code rates and thus the desired system data rates can be varied according to the mode of transmission and specific communication objectives. For diversity purposes, a further reduction of the data rate can be obtained by redundant transmission of data on another subband in a following time slot (time-domain spreading), or by forcing a conjugate-symmetric input of the IFFT block (frequency-domain spreading). Prior to modulation, the coded bit stream is interleaved in two stages (symbol-interleaving followed by tone-interleaving) to provide additional robustness against burst errors.

In the following stage, the coded and interleaved bit stream is fed into a QPSK Gray-coded constellation mapper. The output complex subcarriers are then grouped in blocks of 100 tones, which are further combined with the evenly spaced pilot tones – in addition to guard and zero tones near the band edges – in order to enable robust coherent detection against carrier-frequency offset (CFO) and phase-noise impairments at the receiver. The resulting 128-long symbol is then introduced in parallel to the actual OFDM modulation block. The latter basically performs the inverse discrete Fourier transform (IDFT) on the vector of complex tone coefficients, and is often implemented in practice by the computationally efficient N-point inverse fast Fourier transform (IFFT) of a power-of-two-size N.

Due to the properties of the IDFT, the subcarriers comprising the MB-OFDM symbol have a sinc function shape, and partly overlap in the frequency domain. This significantly increases the spectral efficiency of the modulation scheme as compared to conventional non-overlapping multi-carrier systems, but implies that the separation of the different tones at the receiver cannot be done by bandpass filtering.

The discrete time-domain output sequence is now expanded by inserting the cyclic prefix and guard interval to form the actual MB-OFDM discrete-time symbol. The cyclic prefix is generated by copying the last N_{CP} values of the IFFT output and inserting them in front of the symbol, to combat the dispersion effects of the channel and to collect maximum multipath energy. Since the addition of a cyclic prefix decreases the throughput of the system, the overhead is an important design parameter, which must be chosen in a tradeoff between robustness against inter-symbol interference and effective data rate. The guard interval on the other side ensures enough time (ca. 9.5 ns) for the frequency synthesizers at both the transmitter and the receiver to switch between the different subbands.

After digital-to-analog conversion, the complex baseband signal during the lth MB-OFDM symbol period can be described by

$$s_l(t) = \sqrt{E_{\mathrm{S}}} \sum_{k=0}^{N-1} d[k] \mathrm{e}^{\mathrm{j}2\pi k \Delta f (t - T_{\mathrm{CP}})}, \qquad (18)$$

with $t \in [0, T_{\mathrm{FFT}} + T_{\mathrm{CP}}]$, with $\Delta f = 1/T_{\mathrm{FFT}}$ being the subcarrier spacing, and with T_{CP} and T_{FFT} corresponding to the duration of the cyclic prefix and IFFT operations, respectively. The $d[k]$ are the complex subcarriers. The

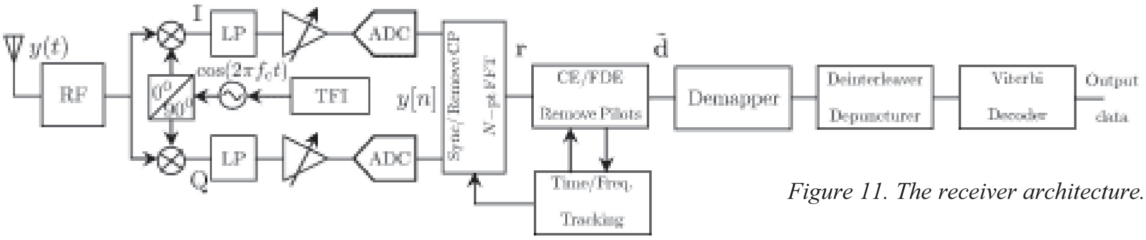

Figure 11. The receiver architecture.

baseband signal, $s_l(t)$, is further up-converted to the corresponding RF center frequency, f_C^l, resulting in the real-valued signal $x(t)$ to be transmitted over the wireless channel:

$$x(t) = \sum_{l=0}^{N_S-1} \mathrm{Re}\left\{ s\left(t - lT_{\mathrm{sym}}\right) e^{j2\pi k f_C^l t} \right\}, \tag{19}$$

where N_S is the total number of transmitted symbols and T_{sym} is the duration of the MB-OFDM symbol.

The center frequency, f_C^l, in each time slot is controlled by the time-frequency interleaver according to the specified time-frequency code (TFC) of transmission. The proposed six time-frequency codes for BG 1 have been designed to minimize the interference between collocated networks/piconets, and can therefore be interpreted as logical channels in the frequency domain used to enable multiple-user access in the system. For the lth transmitted symbol, the center frequency of the corresponding subband of transmission can be determined for a given time-frequency code $\mathbf{c}_u = \{c_u[0], \ldots, c_u[N_C - 1]\}$ by

$$f_C^l = f_{C_1} + \left\{ c_u\left[l - \left\lfloor \frac{l}{N_C} \right\rfloor N_C \right] - 1 \right\} B, \tag{20}$$

where f_{C_1} is the center frequency of the first subband, B is the frequency subband separation, N_C is the length of the time-frequency code, and $\lfloor \bullet \rfloor$ denotes the floor operation.

5.2 Receiver Architecture

The receiver architecture of the proposed MB-OFDM system is based on the zero-IF topology, in which the RF signal is directly down-converted to baseband, thus minimizing the number of signal-processing stages and the overall receiver power consumption [31, 32]. Through complex mixing and subsequent low-pass filtering in the baseband, this architecture is able to suppress nearby interferers, remove the undesired image of the signal, and select the desired channel. Despite eliminating the need for intermediate-frequency (IF) stages and bulky off-chip image rejection filters, the zero-IF receiver introduces the problems of dc offsets, $1/f$ noise, LO leakage, and I/Q imbalance. To overcome these challenges, careful layout design, advanced digital-signal-processing, and/or alternative (e.g., low-IF) receiver architectures have to be considered.

In an MB-OFDM zero-IF receiver, as shown in Figure 11, the received signal, $y(t)$, behind the antenna is first passed through the RF analog front end, consisting of a bandpass pre-select filter and a low-noise amplifier. The former serves to suppress out-of-band energy, to pre-select the desired frequency band, and to thus partially reject higher noise frequency components and image-band signals. The latter is used to amplify extremely weak signals without introducing additional distortions. The output of the RF block is then directly down-converted to baseband in in-phase (I) and quadrature (Q) branches. The resulting I and Q components are further passed in parallel through a low-pass (LP) anti-aliasing filter and an analog-to-digital converter (ADC). The discrete-time signal, $y[n]$, is then introduced in parallel to a coarse time/frequency synchronization block. This has to determine the arrival of a packet, as well as setting the boundary of each frame and the proper window for the following FFT operation.

5.3 Synchronization, Channel Estimation, and Frequency-Domain Equalization

Most coarse timing algorithms for OFDM systems presented in the literature are based on the cross-correlation metric between repeated preamble symbols. However, this approach has to be modified in order to account for the frequency-hopping characteristic of UWB MB-OFDM systems, where adjacent preamble symbols occupy different subbands. Since the receiver oscillator output is fixed until the corresponding time-frequency code and subband center frequency have been acquired, only a portion of the received preamble symbols will be correctly down-converted to baseband.

On the other hand, the task of frequency synchronization is to correct the frequency offset caused by the different outputs of the transmitter and receiver local oscillators. The estimate of the carrier frequency offset (CFO), $\Delta\tilde{f}_C$, can be calculated using the phase of the sampled output correlation metric, $M[n_0]$, i.e.,

$$\Delta\tilde{f}_C = \frac{\measuredangle\{M[n_0]\} f_S}{2\pi N}, \tag{21}$$

with $n_0 = \arg\max_n \{M[n]\}$ being the sample value for which the correlation metric reaches a maximum and around which the FFT window has to be centered.

After block-wise removal of the cyclic prefix and guard interval, the symbol vector, $\mathbf{y}$, is transformed back to the frequency domain. This task is performed by the FFT block, which essentially implements a computationally efficient algorithm to calculate the discrete Fourier transform of a signal.

Since the effects of multipath propagation are mainly included in the cyclic prefix, removing this redundant part at the receiver minimizes the influence of inter-symbol interference on the received MB-OFDM signal. However, the frequency selectivity of the channel may still cause deep fades in signal level, and thus decrease the probability of correct detection and degrade overall system performance. In order to compensate for the effects of the multipath channel, the output of the FFT operation is processed in the frequency domain by the channel-estimation (CE) and frequency-domain equalizer (FDE) block. The channel-estimation algorithm itself is based on the transmission of identical training sequences, which are known to the receiver and can therefore be compared with the received symbols to extract the actual response of the channel. The channel estimation is performed in the frequency domain for each subcarrier and subband of transmission by averaging the received channel-estimation parts of the preamble and multiplying them with the known preamble coefficients, $p^*[k]$. The estimated channel coefficients, $\hat{H}_{eff}[k,m]$, can be written as

$$\hat{H}_{eff}[k,m] = \frac{1}{M}\left\{\sum_{\mu=0}^{M-1} r^{\mu}[k,m]\right\} p^*[k], \qquad (22)$$

with M being the number of averaged training symbols, $m = 0 \ldots N_{\mathrm{SB}}$ being the index of the subband, and k being the subcarrier index.

The estimated channel coefficients, $\hat{H}_{eff}[k,m]$, can now be used to compensate for the effects of the multipath channel. Since the signal bandwidth is subdivided into N parallel carriers/channels, the subcarrier spacing becomes smaller than the coherence bandwidth of the frequency-selective channel, which is now approximated as being frequency flat for a single subcarrier. Compensation for the channel effects can therefore be performed by a single-tap frequency-domain equalizer, which essentially multiplies the received user data tones, $r[k,m]$, with the complex conjugate of the estimated channel frequency response, $\hat{H}^*_{eff}[k,m]$ of the respective subband. Omitting the subband index for simplicity, the outputs of the frequency-domain equalizer are the equalized subcarriers

$$\tilde{d}[k] = d[k] H_{\mathrm{eff}}[k] \frac{\hat{H}^*_{eff}[k]}{\left|\hat{H}_{eff}[k]\right|^2} + W[k] \frac{\hat{H}^*_{eff}[k]}{\left|\hat{H}_{eff}[k]\right|^2}$$

$$= \hat{d}[k] + \tilde{W}[k], \qquad (23)$$

where the $d[k]$ are the subcarriers of the transmitted payload MB-OFDM symbol.

The time- and frequency-tracking block in Figure 11 serves for fine synchronization based on the pilot tones, which are evenly scattered across the MB-OFDM symbols. In the next step, the complex-valued tones are rearranged to their original positions (with guard and pilot subcarriers being removed) and further de-mapped to binary data. This operation corresponds to the reverse of the constellation mapping performed at the transmitter side. After de-interleaving and de-puncturing, a Viterbi convolutional decoder is used to remove the controlled redundancy and retrieve the binary data payload.

5.4 MIMO Techniques

However, the capacity and coverage range of the MB-OFDM UWB system presented is limited by the available spectrum and level of transmitted signal power, as defined by the FCC regulations. To further improve its spectral efficiency and link reliability, the employment of multiple-input multiple-output (MIMO) techniques for communications is often considered a viable solution to the capacity bottleneck, as the rich scattering present in indoor environments provides an ideal scenario for MIMO applications. By including the spatial dimension, i.e., the use of multiple antennas at both the transmitter and receiver sides, MIMO MB-OFDM UWB systems can effectively turn multipath propagation, generally considered a drawback in wireless communications, into an advantage, to linearly increase capacity or improve the quality of transmission in terms of BER (bit error rate).

Traditionally, multiple antennas have been applied with space-time coding (STC) techniques to combat the channel fading caused by multipath propagation and to achieve maximum diversity gain [33]. Alternatively, in spatial multiplexing (SM) schemes (as used, e.g., in ZF, ML, MMSE, or V-BLAST receivers), the user data can be split into several independent sub-streams, which are then simultaneously transmitted by the corresponding antennas. The receiver, having estimated the MIMO channel, recovers these individual sub-streams by various decoding algorithms and combines them into the original data stream.

While the receiver has an estimate of the channel effects and may thus provide some receiving diversity, the system can not achieve any transmitting diversity gain since the individual streams are completely independent from each other, since they carry totally different data. In contrast to spatial-diversity schemes aiming to counteract fading, spatial multiplexing implies that fading can, in fact, be beneficial, through increasing the degrees of freedom available for communication. Essentially, if the path gains between individual transmitting-receiving antenna pairs fade independently, the MIMO channel itself can be subdivided into multiple spatial data pipes, which then allow for a nearly linear increase in throughput at the same power levels [34, 35].

However, the use of multiple antennas implies an increase in hardware costs and computational complexity of the system, as some of the blocks have to be replicated for each antenna branch. The main challenge is therefore to find a reasonable tradeoff between the capacity gain achieved and the complexity incurred as a result of the use of multiple antennas.

6. UWB Localization

Whereas different conceptions exist about the distinction between positioning and localization, both expressions are used interchangeably in this paper. They are defined as the action of estimating the position or location of a mobile object or person within a fixed or variable coordinate system. Many methods exist to locate different moving objects or persons; only a couple of those are good candidates for fulfilling the task of reliable and precise localization in difficult environments, especially indoors. Optical systems using lasers, infrared, or cameras, as well as acoustic systems using ultrasonic waves, have the drawback of always needing direct line-of-sight (LoS) conditions, which cannot be guaranteed in all cases under such circumstances. Furthermore, systems based on proximity localization (Cell-ID) – using, e.g., inductive signals or RFID – are quite inaccurate and elaborate. In contrast, systems based on radio waves have the feasibility of being very accurate and having certain material penetrability. In a radio-based localization system, the position of a radiating mobile unit is typically estimated via the analysis of signals received at a certain number of sensors, or vice versa. This approach is normally based on measuring ranges, range differences, or angles between mobile units and sensors, and subsequently processing the range information into a position estimate. This is discussed in more detail in the following.

6.1 Range Estimation

Range estimation is defined as the action of estimating the distance between a mobile device and a known sensor location. To start with a simple model, the received signal, $r_i(t)$, at a certain sensor, i, can be expressed as an attenuated and delayed version of the transmitted signal, $s(t)$, with additive noise, $n_i(t)$:

$$r_i(t)=\alpha_i(d_i)s\left[t-\tau_i(d_i)\right]+n_i(t), \qquad (24)$$

where $\alpha_i(d_i)$ denotes a distance-dependent attenuation factor, and $\tau_i(d_i)$ is the absolute time of arrival at sensor i, which equally depends on the traveled distance. The distance, d_i, can now be estimated either from the attenuation factor or from the time of arrival. Methods that utilize the first parameter are usually classified under the term received signal strength (RSS). Although usually simple to implement since signal estimation is commonly done in every type of receiver, the absence of both valid and accurate attenuation models prevents the received signal strength method from achieving centimeter ranging accuracies. It is thus advantageous to estimate the distance from the channel delay, $\tau_i(d_i)$, which is further supported if a more-realistic channel model is utilized. In typical indoor environments, the severe multipath occurrence can be modeled using a tapped-delay channel model, $h(t)=\sum_{l=1}\alpha_l\delta(t-\tau_l)$, where α_l and τ_l are the attenuation factor and the delay of the lth path, respectively:

$$r_i(t)=\sum_{l=1}^{L}\alpha_{l,i}(d_{l,i})s\left[t-\tau_{l,i}(d_{l,i})\right]+n_i(t). \qquad (25)$$

Now, in the line-of-sight case, the distance information can be found in estimating the first arriving path, namely $\tau_{1,i}(d_{1,i})$, which represents the direct distance between the mobile unit and sensor i. In such channels, the capability of ultra-wideband signals appears, since the extensive bandwidth leads to a good time resolution, and hence to a good distinction ability between the first path and closely arriving subsequent paths. In theory, this fact can be supported by the Cramer-Rao lower bound, which is widely used as a bound for an unbiased estimator. In the case of Equation (24), if $r_i(t)$ is assumed to be a stationary Gaussian process, and the noise, $n_i(t)$, is assumed to be made up of identically distributed zero-mean stationary Gaussian processes, the variance, $\sigma_{\hat{\tau}}^2$, of the time-delay estimate $\tau_i(d_i)$ is bounded by [36]

$$\sigma_{\hat{\tau}}^2 \geq \frac{1}{8\pi^2\beta_f^2\mathrm{SNR}}, \qquad (26)$$

where SNR represents the signal-to-noise ratio available at the receiver, and β_f is the effective bandwidth of the received signal. This is defined by

$$\beta_f=\left[\int_{-\infty}^{\infty}f^2\left|S(f)\right|^2\mathrm{d}f\Big/\int_{-\infty}^{\infty}\left|S(f)\right|^2\mathrm{d}f\right]^{\frac{1}{2}}, \qquad (27)$$

with $S(f)$ being the Fourier transform of the signal $s(t)$. As can be observed, the impact of the effective bandwidth, β_f, is quadratic, compared to the available SNR, which is linear. Therefore, with a UWB signal of 1.5 GHz bandwidth and 0 dB SNR, a ranging accuracy $\sigma_{\hat{d}}=c\sqrt{\sigma_{\hat{\tau}}^2}$ of below 3 cm can be achieved.

The Cramer-Rao lower bound can also be applied as a lower bound for angle-of-arrival (AoA) estimation at the receiver side [37].

6.2 Positioning and Localization

Different methods can now be used to deduce the position from the range estimates. They all use a couple of time-delay estimates between the mobile unit and $1 \le i \le N$ sensors, and they mainly differ in the time-synchronization architecture of the overall localization system. In time-of-arrival (ToA) systems, the sensors at known locations and the mobile unit must be synchronized. Here, a minimum of three ToA estimates is sufficient to solve for the three-dimensional position of the mobile unit via so-called trilateration algorithms. The solution is either based on geometrical considerations, algorithms from nonlinear optimization theory, or Kalman filtering (cf., e.g., [38; 39, p. 43; 40]. An interesting architecture for achieving the synchronization between the mobile unit and the sensor is the two-way ranging (TWR) method, where both parties serve as transceivers, and the ToA is measured using a ping-pong scheme [41]. Here, each transceiver must perform separate time-delay estimation.

To avoid the synchronization efforts between the mobile unit and sensors, the time difference of arrival (TDoA) technique can be used, where the reception time differences at different sensors are measured. Here, only the sensors must be synchronized among each other. Although this task is usually achieved via synchronization cables, long-term stable clocks or the so-called differential time difference of arrival (DTDoA) could be alternatives, which again bring along their own drawbacks [42, 43]. With at least four distributed sensors, the unknown time offset towards the absolute reception time at one specific sensor can be eliminated and a position estimate can be found, again, via geometrical, nonlinear optimization algorithms, or Kalman filtering (cf., e.g., [44; 45; 46, p. 176].

Finally, the angle-of-arrival (AoA) method estimates the angle of the incident wave using, e.g., beamforming or TDoA approaches within one single sensor. Here, triangulation algorithms solve for the wanted position [40; 47, p. 43].

All methods described have their own advantages and drawbacks. Usually, localization application and environment are the main factors that decide which architecture should be used for the given scenario. In addition, combinations of the methods described offer interesting possibilities, e.g., a combination of AoA and TWR would lead to a two-dimensional position solution with a single sensor.

6.3 Major Error Sources of UWB Localization

Although ultra-wideband has its benefits for robust accurate localization, several conditions have to be fulfilled to take advantage of these:

- The signal structure must enable the receiver to detect the arrival time as exactly as possible,
- The signal must have the possibility of traveling along a direct line-of-sight path, and
- The receiver must detect the correct line-of-sight path in multipath and interference environments.

As mentioned above, the first condition is mainly accomplished using very short UWB pulses and an appropriate receiver architecture. However, the second and third conditions are affected not only by the receiver architecture, but also heavily by the environment of the localization scenario. The later has been identified as being

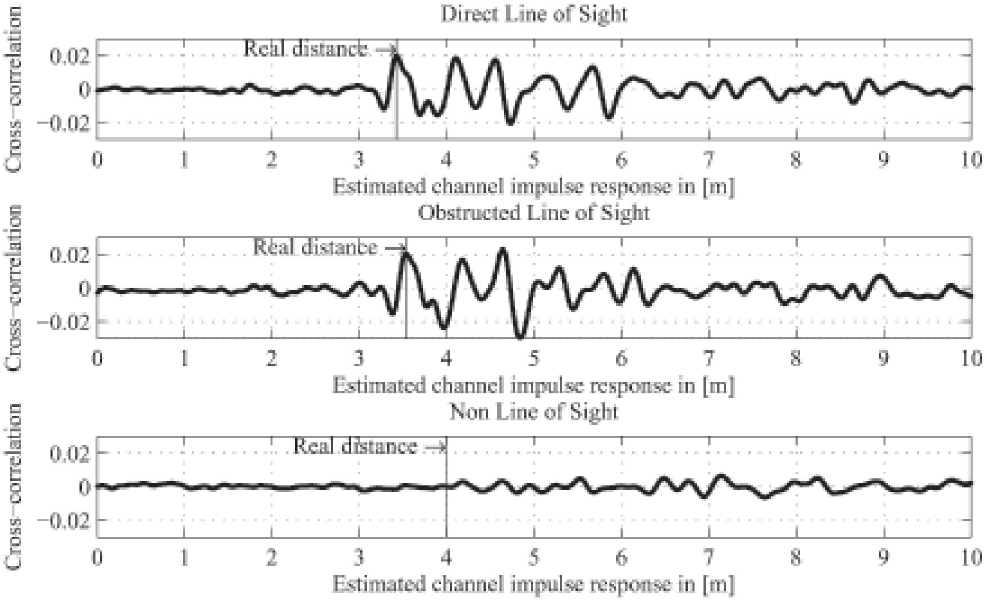

Figure 12. The estimation of the channel impulse responses for real measurements in an indoor laboratory environment.

one major source for ranging error [41, 48]. If, for example, people, objects, or walls attenuate or block the direct signal, a typically positive ranging offset will occur, and will mostly appear as a bias in the position error. This becomes especially critical if the minimum number of channels needed for a position solution does not have the direct line-of-sight condition.

Figure 12 shows the three different channel conditions mentioned. They have been measured in a laboratory room of the IKT, with a digital template-correlation receiver. As can be seen, even in the case of direct line of sight, several multipaths are observable; however, the correct distance can be estimated at the maximum of the cross-correlation function. The second case, with maximum energy at a later path than the direct case, is called obstructed line of sight. To detect the real distance in such a channel condition, a simple maximum detection is not sufficient, anymore. Here, a method called firstmax can be used, which searches the region before the maximum for other paths, the energy of which is a certain percentage lower than that of the maximum [41, 49]. Using such a strategy, it is possible to detect the real distance in obstructed line-of-sight cases. However, the difficulty is to define the threshold that is used for the search criterion, and the length of the search region, which mainly depends on the range of the transceivers. The third channel condition, as shown in the bottom graph of Figure 12, is the non-line-of-sight (NLoS) case, where the path energies are quite small and additionally arrive later than the real distance. A correct estimation of the time of arrival is thus not anymore possible.

However, two consecutive strategies can be utilized to deal with such situations. The first goal is to sense if such a situation occurs. This so-called non-line-of-sight detection can be based purely on time series of the range estimates. Here, simple methods, such as a running variance, and more complicated methods, such as hypothesis testing on different error distributions, have been proposed [50-53]. However, the necessity of a statistical significance contrasts with the need for a small latency of detection for a robust localization system. Approaches that circumvent the latency are based on more information out of the channel impulse response. A sudden decrease of SNR could indicate the movement into a non-line-of-sight constellation. In addition, hypothesis testing from the shape of the channel impulse response could also distinguish between line of sight and non-line of sight [46, p. 191; 54; 55]. However, the suitability of these methods in reality has not yet been proven. Finally, methods based on redundancy of the range estimates can try to detect non-line-of-sight situations during position calculation, using, e.g., minimax or least-square approaches [56, 57]. Even though these methods work in real environments, the existence of enough line-of-sight channels in realistic scenarios is probably a quite seldom occurrence.

If the non-line-of-sight detection task has succeeded, the second strategy is called non-line-of-sight mitigation. The main idea is to use the information that one or more channels are non-line-of-sight, and to try to still get an appropriate position estimate. Next to the stated redundancy approach, usual tracking algorithms based on, e.g., extended Kalman or particle filters and map-matching methods can be utilized to still achieve accurate localization [58-60]. Furthermore, complementary sensors, such as inertial measurement units, could help to deal with such situations [61].

7. Conclusion

The aim of this paper was to give a broad overview of UWB systems for localization and communication. The most-widely-known pulse shapes were discussed, and a rather generic unification of modulation schemes was presented. Moreover, statistical and deterministic channel models were introduced, where the impact of antennas was taken into account. A succeeding section dealt with multi-band OFDM, this having recently been commercially deployed, with a straightforward extension to multi-antenna systems. In the last section, on localization, the major challenges were pointed out, and mitigation techniques for the demanding non-line-of-sight scenario were illustrated. Note that numerous contributions discussing modulation schemes, for example, can be found in the references in much deeper detail. A comprehensive overview about the state-of-art of UWB was given in [62].

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IUCAF Annual Report for 2006

1. Introduction

The Scientific Committee on Frequency Allocations for Radio Astronomy and Space Science, IUCAF, was formed in 1960 by its sponsoring Scientific Unions, URSI, IAU, and COSPAR. Its brief is to study and coordinate the requirements of radio frequency allocations for passive (i.e., non-emitting) radio sciences, such as radio astronomy, space research and remote sensing, in order to make these requirements known to the national and international bodies that allocate frequencies. IUCAF operates as a standing inter-disciplinary committee under the auspices of ICSU, the International Council for Science. IUCAF is a Sector Member of the International Telecommunication Union (ITU).

2. Membership

At the end of 2006 the composition of membership for IUCAF was:

URSI	S. Reising (Com F)	USA
	U. Shankar (Com J)	India
	W. Swartz (Com G)	USA
	A. Tzioumis (Com J)	Australia
	W. van Driel (Com J Chair)	France
IAU	H. Chung	Korea
	R.J. Cohen († 11/2006)	UK
	D.T. Emerson	USA
	M. Ohishi	Japan
	K.F. Tapping	Canada
COSPAR	J. Romney	USA
at large:	W.A. Baan	Netherlands
	K. Ruf	Germany

In November 2006, we lost Jim Cohen, aged 58, who had been active in protecting radio astronomy from interference for more than two decades. He was Chair of IAU Commission 50 on the Protection of Existing and Potential Observatory Sites in 2000-2003, and an IUCAF member since 1994.

IUCAF also has a group of Correspondents, in order to improve its global geographic representation and for issues on spectrum regulation concerning astronomical observations in the optical and infrared domains.

3. International Meetings

During the period of January to December 2006, its Members and Correspondents represented IUCAF in the following international meetings:

April:	ITU-R Task Group 1/9 (Compatibility between passive and active services) in Geneva, Switzerland
July:	36th COSPAR Scientific Assembly in Beijing, China
August:	XXVIth General Assembly of the International Astronomical Union in Prague, Czech Republic
	ITU-R Working Party 7D (radio astronomy) in Geneva, Switzerland
September:	ITU-R Task Group 1/9 (Compatibility between passive and active services) in Geneva, Switzerland
	Space Frequency Coordination Group meeting SFCG-26 in Bonn, Germany

Additionally, many IUCAF members and Correspondents participated in numerous national or regional meetings (including CORF, CRAF, RAFCAP, the FCC etc.), dealing with spectrum management issues, such as the preparation of input documents to various ITU fora.

3.1 IUCAF Business Meetings

During 2006 IUCAF had a face-to-face committee meeting before each of the ITU meetings listed above, with the purpose of discussing issues on the agenda of the meetings in preparation for the public sessions. During these ITU sessions, typically lasting a week to 10 days, ad-hoc meetings of IUCAF were held to discuss further its strategy. Also discussed were other IUCAF business, such as action plans for future workshops and summer schools or initiatives and future contributions to international spectrum management meetings.

Although such face-to-face meetings have been convenient and effective, throughout the year much IUCAF business is undertaken via e-mail communications between the members and correspondents.

4. Contact with the Sponsoring Unions and ICSU

IUCAF maintains regular contact with the supporting Unions and with ICSU. The Unions play a strong supporting role for IUCAF and the membership is greatly encouraged by their support.

IUCAF members actively participated in national URSI meetings, in IAU Colloquia and Symposia and in the 2006 IAU General Assembly and COSPAR Scientific Assembly.

IUCAF members have played an active role in the redaction of the URSI White Paper on Solar Power Satellites (SPS). IUCAF's objective was to ensure that it presents a balanced discussion of the SPS technology, including an evaluation of the risks involved, in particular to radio science. Unwanted radio emissions from SPS systems must be suppressed sufficiently to avoid interference with other radio services and applications, in accordance with the provisions of the Radio Regulations of the ITU.

In view of a the possibility, actually under study at the ITU, of including in the ITU-R Radio Regulations, which form the framework for international spectrum management, frequency allocations in the infrared and optical wavelength domain, IUCAF continued its consultations with members of the optical/infrared astronomy community. At the 2006 IAU General Assembly the IUCAF Chair became a member of the Organizing Committee of IAU Commission 50 on the Protection of Existing and Potential Observatory Sites.

Pursuing its brief, IUCAF continued its activities towards strengthening its links with other passive radio science communities, in particular in space science, and defining a concerted strategy in common spectrum management issues. As a result of meetings with representatives of the COSPAR Executive, IUCAF will organize a two-day Symposium on "Spectrum Management and COSPAR: Keeping Passive Radio Observations Free of Interference" at the 2008 COSPAR Scientific Assembly. The Statement of the IAU to the 43rd Session of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) included a description of the role of IUCAF and current issues within its brief on the preservation of astronomical observations in space.

5. Protecting the passive Radio Science Services

At the ITU, the work in the various Working Parties and Task Groups of interest to IUCAF was focused largely on the preparations for WRC-07, the ITU World Radiocommunication Conference to be held in 2007.

Of particular concern to IUCAF is the protection of the 1400-1427 MHz passive band, which contains the heavily observed interstellar 21-cm neutral hydrogen line and which is used to measure soil moisture and ocean salinity, from unwanted emissions from fixed-satellite service (FSS) feeder links in nearby bands. A decision on suppressing these frequency allocations to the FSS is foreseen at WRC-07, based on studies that were assessed in ITU-R Working Parties 7C and 7D, specializing in Earth exploration by satellites and in radio astronomy, respectively.

ITU-R Working Party 7D (radio astronomy) has also worked towards a provisional agenda item for the WRC to be held in 2011 on the allocation of frequencies by the ITU in the 275 to 1000 GHz frequency range, where astronomical observations are already being made on a regular basis.

In 2006 ITU-R Task Group 1/9 finished its work on the protection of passive services, specifically the radio astronomy service and the Earth exploration-satellite (passive) service, from unwanted emissions of active services in adjacent and nearby bands. This has resulted in an update of the tables of threshold levels used for consultation between the passive and active radio services in Recommendation ITU-R SM.1633. Of particular concern to IUCAF is the protection of the 1610.6-1613.8 MHz radio astronomy bands, which contain important spectral lines of the interstellar OH molecule.

6. IUCAF-Sponsored Meetings

In 2006, IUCAF worked towards the organization of three future international meetings: RFI2007, a Workshop on Mitigation of Radio Frequency Interference in Radio Astronomy, planned to be held in Manchester in October 2007, a Symposium on on "Keeping Passive Radio Observations Free of Interference" planned for the 2008 COSPAR Scientific Assembly in Montreal, and the 2008 Summer School on Spectrum Management for Passive Radio Sciences, planned to be held in Korea.

7. Publications and Reports

IUCAF has a permanent web address, http://www.iucaf.org, where the latest updates on the organization's activities are made available. All contributions to IUCAF-sponsored meetings are made available on this website.

8.Conclusion

IUCAF interests and activities range from preserving what has been achieved through regulatory measures or mitigation techniques, to looking far into the future of high frequency use and giant radio telescope use. Current priorities, which will certainly keep us busy through the next years, include band-by-band studies for cases where allocations are made to satellite down-links close in frequency to the radio astronomy bands, the coordination of the operation in shared bands of radio observatories and powerful transmissions from downward-looking satellite radars, the possible detrimental effects of ultra-wide band transmissions and high-tension power line communications on all passive services, and studies on the operational conditions that will allow the successful operation of future giant radio telescopes.

IUCAF is grateful for the moral and financial support that has been given for these continuing efforts by ICSU, URSI, the IAU, and COSPAR during the recent years. IUCAF also recognizes the support given by radio astronomy observatories, universities and national funding agencies to individual members in order to participate in the work of IUCAF.

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ISES Annual Report for 2006

The International Space Environment Service, in its modern form, has its origins in the International Geophysical Year, largely because of the efforts of Alan Shapley, Thus the death of Dr. Shapley on October 20, 2006 at age 87 marks the passing of a person who has played a key role in the development of ISES and space weather forecasting. Dr Shapley served as Vice-Chairman of the U.S. Committee for the International Geophysical Year and was a very active member of the International Special Committee for the IGY as coordinator for the World Days Program and the International Geophysical Calendar. He was also instrumental in setting up the system of Regional Warning Centers and was for many years the director of the International Ursigram and World Days Service (IUWDS), the fore-runner of ISES. David Boteler, Helen Coffey, and Joe Kunches had the privilege of interviewing Dr. Shapley a few years ago and he was very helpful in filling in the history of IUWDS.

When Dr. Shapley retired from IUWDS in 1973 the internet had not yet been invented, forecasting magnetic disturbances was still seen as a waste of time by many scientists, and the term "space weather" had not been invented. Thus Dr Shapley's words, written in July 1973 in the Introduction to the third edition of the URSIgram code book, show what a keen vision he had of the future:

"I am convinced that still more huge steps are before us. At some time, whether before the year 2000 or after, there will be a full-flowered 'Weather Service for the Space Environment' in several countries, tied together by a world organisation of space environment services. We will not be struggling along on an ad hoc basis as now, we will be recognized as a needed, bona fide activity both for practical space activities, manned and unmanned, and for increasing complex scientific experiments and explorations."

Extensive space weather services are now provided by twelve Regional and Associate Warning Centres around the world, located in China (Beijing), USA (Boulder), Russia (Moscow), India (New Delhi), Canada (Ottawa), Czech Republic (Prague), Japan (Tokyo), Australia (Sydney), Sweden (Lund), Belgium (Brussels), Poland (Warsaw) and France (Toulouse) and a collaborative expert centre at the European Space Agency. The internet has greatly improved the flow of space weather data into the forecast centres and the delivery of space weather forecasts to users. All this is coordinated by the organisation founded by Shapley, which changed its name, in 1996, to the International Space Environment Service.

ISES Regional Warning Centres are located in every populated continent except Africa and South America. Consequently, ISES decided that an appropriate way to celebrate the 50th anniversary of ISES in its modern form would be to encourage the establishment of regional warning centres to bring space weather forecast services to those regions. In response to this objective ISES representatives attended the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) 11th Quadrennial Symposium in Rio de Janeiro, 6-11 March 2006. A special meeting was organised for South American scientists interested in space weather and following the SCOSTEP meeting a visit was made to the Brazilian National Space Institute (INPE). Contacts were also made with South African scientists at Hermanus Magnetic Observatory that has become a national centre of excellence for space physics activities and an HMO representative attended the ISES meeting in Beijing. Discussions are continuing with both groups about how ISES can help them develop space weather services.

With mankind's activities no longer limited to the planet Earth, but expanding out through the solar system, there is need for knowledge about the space environment that will be encountered. At present the concern is about space weather effects on satellites but will become focussed on radiation hazards when manned missions return to the Moon and eventually on to Mars. ISES, under the framework of the International Heliophysical Year, is leading a coordinated investigation program: "Space Weather in the Solar System (SWISS)". This aims to provide information on current, past and future (forecasted) space weather conditions in the Solar system, useful for planned and current space missions and to provide boundary conditions for more detailed models and case studies. It will also provide a common frame for numerical models of solar wind-planetary magnetospheres interaction during quiet and disturbed times. Further details of this joint ISES/IHY program are available at http://ihy2007.org.uk/CIPs.shtm.

ISES provides a number of services related to space activities. The International Geophysical Calendar gives a list of 'World Days' during which scientists are encouraged to carry out their experiments. The monthly Spacewarn Bulletins, prepared on behalf of COSPAR, summarize the status of satellites in earth orbit and in interplanetary space. ISES is also a sponsor of the AGU journal: "Space Weather: The International Journal of Research and Applications" and sponsored the space weather session at the 36th COSPAR Scientific Assembly held at the Beijing Institute of Technology (BIT) in July 2006. ISES has also been involved in discussions with the international aviation community about providing new warnings of problems with HF radio communications and radiation hazards for commercial aircraft flying on trans-polar routes.

The annual meeting of the ISES Directing Board was held at the Beijing Friendship Hotel on 15 July 2006 and was organised by RWC China. On the following day the ISES delegates were able to see the forecasting centre at one of the component institutes of RWC China and also visited the Huairou Solar Observing Station (HSOS) which is located 60 km north of Beijing. The 4-year terms of the ISES Director, David Boteler, and Deputy Director, Henrik Lundstedt, came to an end in 2006. Elections were held and both were elected to a second term. The next ISES meeting will be held in Boulder, USA, in April 2007 in conjunction with the Space Environment Center's Space Weather Week. This meeting will be expanded to two days to include sessions on forecasting problems encountered during particular space weather events plus discussion of how to utilize new data sources such as from the Solar-B and STEREO satellites.

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ISES Centres

RWC Australia: IPS Radio and Space Services, PO Box 1386, Haymarket NSW 1240, Australia, http://www.ips.gov.au/

RWC Canada: Natural Resources Canada, Geomagnetic Laboratory, 7 Observatory Crescent, Ottawa Ontario K1AOY3, Canada, http://spaceweather.ca/

RWC Czech Republic: Institute of Atmospheric Physics, Academy of Sciences, Bocni II, 141 31 Prague 4, Czech Republic, http://rwcprague.ufa.cas.cz/

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RWC Russia: Institute of Applied Geophysics, Rostokinskaya str., 9, 129128 Moscow, Russia, http://www.geospace.ru

World Warning Agency: NOAA Space Environment Center, 325 Broadway, Boulder, CO, USA, http://www.sec.noaa.gov/index.html

RWC Belgium: Solar Influences Data Analysis Center (SIDC), Royal Observatory of Belgium, Ringlaan - 3 - Avenue Circulaire, B-1180 Brussel, Belgium, http://sidc.oma.be/

RWC China: National Astronomical Observatories, Chinese Academy of Science, 20A Datun Road, Chaoyang District, Bejing, China, http://rwcc.bao.ac.cn/

RWC India: National Physical Laboratory, New Delhi – 110012, India, http://npl-cgc.ernet.in

RWC Poland: Space Research Centre, Polish Academy of Sciences, Bartycka 18A, 00-716 Warsaw, Poland, http://www.cbk.waw.pl/rwc/rwc.html

RWC Sweden: Swedish Institute of Space Physics, Scheelev. 17, SE-223 70 Lund, Sweden, http://www.lund.irf.se/rwc

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Collaborative Expert Centre: European Space Agency (ESTEC), Keplerlaan 1, Postbus 299, 2200 AG Noordwijk, The Netherlands, http://www.estec.esa.nl/wmwww/wma/spweather/

URSI and the International Committee on Global Navigation Satellite Systems (ICG)

1. Background

In 1999, the UN General Assembly adopted the "Vienna Declaration on Space and Human Development" (Resolution 54/68). Among others, this Declaration called for universal access to and compatibility of space-based navigation and positioning systems. In 2001, the Committee on the Peaceful Use of Outer Space established the Action Team on Global Navigation Satellite Systems (GNSS). In December 2004, the Action Team presented its report (UNISPACE III), recommending the establishment of an International Committee on GNSS, to facilitate the exchange of information and to promote the development and global use of GNSS. In 2004, in Resolution 59/2, the UN General Assembly invited the system and service providers to consider establishing an international committee on GNSS, in order to maximize the benefits of the use and application of GNSS to support sustainable development. Thus, after a long series of meetings, stretching from August 2001 to December 2005, the ICG was established, and held its inaugural meeting in Vienna in November 2006.

The secretariat is provided by the UN Office for Outer Space Affairs (OOSA) in Vienna. An "open-ended ad-hoc working group" was established to discuss current issues and to prepare the annual plenary meetings of the ICG, mostly by e-mail, but once or twice a year by meeting in Vienna.

The ICG Terms of Reference define three types of participants:

- *Members*: current and future core system providers, regional or augmentation system providers, and States Members of the United Nations;
- *Associate Members*: International and regional organizations and associations dealing with GNSS services and applications (among many others, ICSU is an Associate Member);
- *Observers*: Among others, COSPAR, the ITU, and URSI.

Associate Members and Observers may both advise the Committee and actively contribute to its work, but do not have a vote. There is very little difference between Associate Members and Observers: the latter will not be called upon to contribute financially.

In April 2006, the URSI Board decided to join the ICG as an Observer. URSI's interests range from the development of propagation models and signal processing for radio navigation and positioning to the application of GNSS in radio-science research, and hence cover the working areas of several Commissions.

2. First Plenary Meeting of the ICG (Vienna, November 1-2, 2006)

At the first plenary meeting, the Workplan for the ICG was adopted. This plan defines four working groups:

2.1 A: Compatibility and Interoperability

Five actions were defined, with the USA and the Russian Federation as co-leaders, addressing:

- System interoperability
- Workshops on compatibility of global and regional space-based and ground-based systems
- Identification of concrete steps to improve interoperability and standardization, especially in land-based applications
- Guidelines for the broadcast of natural-disaster alarms via GNSS
- Strategies for the support of mechanisms to detect and mitigate sources of EM interference

2.2 B: Enhancement of Performance of GNSS Services

Co-leaders: India and the European Space Agency

- Development of a reference document on models and algorithms for ionospheric and tropospheric corrections
- Multipath mitigation, especially for mobile users
- Extension to indoor applications

2.3 C: Information Dissemination

Leader: the Office for Outer Space Affairs. It will

- Establish an information portal
- Identify undergraduate and graduate courses
- Prepare a list of relevant textbooks
- Use UN-affiliated Regional Centres for Space Science and Technology Education
- Identify conferences where the work of ICG can be presented
- Propose further mechanisms to promote applications of GNSS

2.4 D: Interaction with National and Regional Authorities and Relevant International Organizations, Particularly in Developing Countries

Co-leaders: Fédération Internationale des Géomètres (FIG), International Association of Geodesy (IAG), and International GNSS Services (IGS).

- Minimum operational performance standards
- Site quality, integrity, and interference monitoring (SQII)
- Strategy for the support of regional reference systems
- Strategies for the support of mechanisms to detect and mitigate sources of EM interference

3. Informal Meeting of the Ad Hoc Working Group (Vienna, 21 February 2006)

3.1 Developments Since the First Plenary Meeting

- The US administration has decided to contribute \$210,000 to the ICG for its running of various activities. This is meant for the support of meetings, invitation of experts from developing countries, etc.
- The Russian government has officially approved participation of the Russian Federation as Member
- The Chinese delegation stated that China was now also ready to approve its membership, but was waiting for the final versions of the Terms of Reference and Workplan
- A CD with the proceedings of the first plenary meeting will be made available by the Secretariat.

3.2 Preparation of the Second Plenary Meeting

The ad hoc working group met in Vienna to discuss current actions and the preparation of the second plenary meeting of the ICG. The second plenary meeting was scheduled for September 5-7 in Bangalore, India, at the invitation of ISRO. India expressed its preference for a later date, between November 2007 and February 2008. However, the working group had a strong preference for a date in 2007. India will reconsider the original schedule, or else host the third meeting in 2008.

The agenda will consist of splinter meetings of the working groups (A, B, C, and D), presentations of the Indian activities related to GNSS, a workshop with invited technical papers, and the formal plenary meeting itself: in total, three days.

Proposed subjects for invited lectures were:

- Global and regional GNSS
- Geodetic Reference Frames (EUPOS, AFREF)
- Atomic time standards and UTC
- Ionospheric and tropospheric models
- Compatibility and Interoperability

All participants in ICG will be requested to indicate their interest in the various working groups or particular actions, and working group leaders are requested to define their points of contact.

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Radio Science Doctoral Abstracts

Salil D. Gunashekar, **An Investigation of the Propagation of 2 GHz Radio Waves Over Sea Paths**, University of Leicester, Department of Engineering, November 2006; E-mail: sdg10@le.ac.uk.
Relevant Commission(s): F

Abstract

Three long-range 2 GHz radio paths were established in the British Channel Islands in order to investigate the characteristics of UHF radiowave propagation over the sea, as part of a project supported by Ofcom, UK. The relationship between specific over-sea propagation mechanisms (such as evaporation ducting and super-refraction) in the lower troposphere and signal-strength distribution patterns has been examined, modeled, and correlated with meteorological parameters. A number of radio meteorological statistics specifically related to evaporation-duct propagation in a temperate region such as the English Channel have been presented to confirm the capability of this key propagation mechanism for guiding radio waves to distances well beyond the normal radio horizon. Evaporation ducting and diffraction appear to be the dominant propagation mechanisms at most times.

Signal-strength enhancements have been observed on all three radio paths, primarily in the late afternoon and evening periods, in the spring and summer months. During periods of enhanced propagation, which occur approximately 8% of the time on a 50 km path, the presence of additional higher-level ducting/super-refractive structures has been verified, and their influence has been modeled with reasonable success. Additionally, the statistical variation of bulk meteorological parameters in the context of enhanced signal propagation has also been examined. The relatively long-term observations made during this study confirm the fact that the constantly changing weather patterns in the troposphere (e.g. the occurrence of anticyclonic weather) are directly responsible for the occurrence of enhanced signals at certain periods of time. The various issues under investigation are of direct relevance in the planning of radio-communication systems operating in the UHF band (e.g., GSM and UMTS) in marine and coastal regions.

Michael A. Saville, ***Multilevel Multipole-Free Fast Algorithm for Electromagnetic Scattering Problems in Layered Media***, Department of Electrical & Computer Engineering, University of Illinois at Urbana-Champaign, October 2006; E-mail: michael.saville@afit.edu.
Relevant Commission(s): B

Abstract

A multilevel multipole-free algorithm is presented for solving electromagnetic scattering problems in the vicinity of a half space or layered medium. By replacing the multipole expansion in the fast inhomogeneous plane-wave algorithm (FIPWA) with a multipole-free expansion, this new algorithm is simpler to derive and retains $O(N \log N)$ scaling in memory and processing time. To develop this new algorithm, known as the multipole-free fast inhomogeneous plane-wave algorithm (MF-FIPWA), error control is established for arbitrary accuracy. In addition, comparison of the memory usage and simulation time is presented for FIPWA and MF-FIPWA for moderate- to large-scale problems. Various alternate approaches to implementing MF-FIPWA are discussed in terms of how the fast algorithms set up translation matrices and where gains can be made. Finally, details of the advantages of using nonuniform sampling are provided. Results show 30% savings in memory usage and up to 20% savings in computing the matrix-vector product.

Call for Submissions

In order to encourage dialogue with young radio scientists, the *Radio Science Bulletin* publishes the abstracts of relevant doctoral dissertations or theses in the fields of radio science, as soon as they are approved by universities or other degree-awarding institutions.

We thus call upon supervisors or research-group leaders to bring this opportunity to the attention of recently qualified doctoral graduates, asking them to e-mail their abstracts to the address given below. The date of publication should be given, with full details of the address of the awarding institution, and also an e-mail address for the author. It would also be helpful to indicate which URSI Commissions relate most closely to the doctoral work.

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Radio-Frequency Radiation Safety and Health

James C. Lin

*Mobile Phone Use and Malignant Central Nervous System Tumors**

It has been estimated that there are about two billion users of cellular mobile telephones worldwide. The popularity of cellular telephones is beyond any debate. It's a good guess that most, if not all, users would prefer no links between cellular telephone and health effects, let alone cell-phone use and cancer.

Several epidemiological studies conducted on both sides of the ocean in the past did not reveal much consistent evidence to corroborate cell-phone radiated radio-frequency (RF) energy causing any cancer in humans. However, there have been persistent public concerns about the possible adverse health effects of cellular mobile telephone radiation. Many scientists working in the field have expressed the desire to see more long-term data before drawing a firm conclusion that there is no or minimal effect, especially for brain tumors, which are known to have a latency of 10 years or longer.

Several years ago, a priority was established to conduct a series of epidemiological studies to investigate the relationship between the incidence of cancers in the head and neck and the use of cell phones [1]. The INTERPHONE project was launched by the International Agency for Research on Cancer (IARC), a health-related agency of the World Health Organization (WHO). Priority was given to the incidence of brain tumors and other head and neck tumors because in common usage, nearly half of the cell-phone-radiated RF energy is absorbed by tissues on the side of the head closest to the cell-phone handset.

In these large-scale epidemiological studies, data attainment relied primarily on in-person interviews, conducted by a trained interviewer. Validation studies were conducted to ascertain the accuracy of self-reported use of cell phones by comparing questionnaire answers to information from records of cell-phone-system operators, and to information recorded by software-modified phones.

As mentioned in a previous column [2], the first results of the INTERPHONE study had begun to appear in the scientific literature around early 2005. Some of the results from the reported studies – especially those associated with use of a cell phone for less than 10 years – were very similar to studies on short-term cell-phone use. However, the reported findings associated with use of a cell phone for 10 years or more have been intriguing, to say the least. Most of these have included a relatively small number of study subjects with long-term use or prolonged exposure to cell-phone radiation

A recent publication from an INTERPHONE-related study [3] that reported a connection between malignant brain tumors and long-term use of a cell phone makes the issue difficult to be ignored or easily dismissed. This study was a population-based case-control study on the association of cell-phone use with brain tumors in five northern European countries – Denmark, Finland, Norway, Sweden, and southeast England – where cell phones have been widely used for at least a decade. The study used IARC's INTERPHONE protocol.

Specifically, the study was conducted in Denmark as a whole; 98% of the population in Finland excluding Northern Lapland and Åland; the southern and middle parts of Norway; the geographical areas covered by the regional Cancer Registries in the Umeå, Stockholm, Gothenburg, and Lund regions in Sweden; and the Thames region of southeast England. Incident cases were subjects residing in the study areas and diagnosed with gliomas, as defined by the International Classification of Diseases for Oncology [4]. This classification is used principally in tumor or cancer registries for coding the site and the histology of both benign and malignant tumors, usually obtained from a pathology report. Gliomas, including astrocytomas and glioblastomas, are the most common malignancy of the central nervous system in adults, and the prognosis is extremely poor.

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*A version of this article also appeared as James C. Lin, "Malignant Brain Tumors from Cellular Mobile Telephone Radiation," *IEEE Antennas and Propagation Magazine*, 49, 1, February 2007, pp. 212-214; Copyright 2007 IEEE.

In order to increase the number of study subjects and to include a younger age group, the study population reported in the latest paper was based on a wider age range (18-69 years of age) than that in the INTERPHONE study. Eligible cases were from 2000 and 2004, and identified through neurosurgery, oncology, and neurology departments in the study areas. Cases were checked against the regional or national cancer registries to enhance and evaluate completeness of the database. Controls were selected from national population registers, or randomly selected from a list with frequency-matching on age, sex, and region of residence of cases.

Several characteristics related to cell-phone use were investigated, including ever and regular cell-phone use, the cumulative number of calls, the cumulative hours of cell-phone use, lifetime years of use, and years since first use. Moreover, the cumulative number of calls and the cumulative hours of cell-phone use were adjusted for the reported use of hands-free devices. The total number of subjects included 1,521 glioma patients and 3,301 controls. Of these, 893 (58.7%) and 1,530 (46.4%) were males, and 628 (41.3%) and 1,771 (53.7%) were females, in the respective groups.

The study showed no overall association between regular cell-phone use and increased risk of malignant brain tumors with duration of use, years since first use, cumulative number of calls, or cumulative hours of use. For more than 10 years of cell-phone use, on the same side of the head where the tumor was located, an increased odds ratio (OR) of 1.39 (95% confidence interval CI 1.01, 1.92) was reported. This indicated a possible 39% increase in risk of gliomas in the RF-irradiated part of the brain associated with long-term use of cell phones.

Interestingly, the INTERPHONE team from Germany had also reported last year an increase in glioma following more than 10 years of cell-phone use in a population-based, case-control study [5]. The incident cases of glioma among 30-69-year-old patients were ascertained during 2000 to 2003. For a total of 366 glioma cases, the study again showed that use of a cell phone was not associated with an overall increase in brain tumor risk: the OD was 0.98 (95% CI: 0.74, 1.29) for glioma. Among subjects who had used cell phones for 10 years or more, an increased risk was reported for glioma (OD 2.20, 95% CI: 0.94, 5.11). At the time, the authors had suggested that the elevated risk of glioma after 10 years or more of cell-phone use needed to be confirmed by other studies, since the number of long-term cell-phone users in their study was small, and effects of recall bias could not be ruled out.

Actually, another research group from Sweden,, unrelated to the INTERPHONE project, has also reported increased risk of malignant brain tumors following 10 years or more of cell-phone use [6]. In this study, incident cases were recruited between 2000 and 2003, and subjects were between 20-80 years of age at the time of cancer diagnosis [6]. Of the 317 cases, 189 were male and 128 were female. They were living patients residing in the Uppsala/Örebro and Linköping medical regions of Sweden, and had their histopathological diagnoses reported to the regional cancer registries. The study enrolled 692 controls (292 male and 400 female); the mean age was 54 years for cases and 55 years for controls. A significantly increased risk for high-grade astrocytomas was found for cell-phone use greater than 10 years, and the OR increased both with the increasing number of hours of use and the length of use.

A pooled analysis [7] of the results of two case-control studies on malignant brain tumors from the same group, including the one mentioned above, indicated that cumulative lifetime cell-phone use for longer than 2,000 hours was associated with increased risk, with the highest being those who had used a cell phone for 10 years or longer. Moreover, ipsilateral exposure – exposure to cell-phone RF radiation on the same side of the head – was associated with an increased risk for malignant brain tumors.

Thus, while the risk of brain tumors from cell-phone exposures will likely remain controversial for sometime, the latest report opens the door a little wider on the possibility that cell-phone use could lead to brain tumors in humans.

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CONFERENCE REPORTS

EUROPEAN CONFERENCE ON SYNTHETIC APERTURE RADAR
EUSAR 2006

Dresden, Germany, 16 - 18 May 2006

Record participation on EUSAR's 10th anniversary

EUSAR is the only international conference dedicated to SAR techniques, technology and applications. The first EUSAR was held in 1996 in Königswinter, continued 1998 in Friedrichshafen, 2000 in Munich, 2002 in Cologne and 2004 in Ulm. EUSAR had its 10th birthday in Dresden in May 2006. The conference site was the International Congress Centre, one of the most modern and beautiful congress centres in Europe situated on the banks of the river Elbe in the heart of the historical city. The conference was organized by ITG/VDE in conjunction with the Microwaves and Radar Institute of the German Aerospace Center (DLR).

EUSAR 2006 was the biggest and most successful yet. 87 reviewers scrutinized 473 paper submissions, whereby 250 were accepted for oral presentation and 129 for poster presentation. The authors and authoresses came from 33 countries. There were 16 invited sessions covering the most important and topical SAR topics.

We have entered a very dynamic and challenging time for SAR development with the recent launches of the SAR satellites ALOS/PALSAR and SAR-Lupe and a number of other spaceborne systems to be launched soon, i.e. TerraSAR-X, RADARSAT-2, COSMO Skymed, TECSAR, as well as further SAR-Lupe satellites. SAR systems are today an indispensable data source for high resolution 2D and 3D mapping, environmental and disaster monitoring, as well as security related applications. Information extraction has achieved a mature and operational level in a variety of fields, making the contributions of SAR systems to present and future programs like GMES and GEOSS an essential element.

Perhaps the greatest impact of SAR technology has been the development of interferometric measurement modes, enabling three dimensional imaging of the earth's surface and the detection of small surface changes and feature motion. Spaceborne SAR sensors are regularly used to monitor instable urban regions by following the minute phase shifts of natural targets. Airborne SAR instruments are efficient tools to topographically map large areas inaccessible to other methods. Moving scatterers such as surface currents and ships can be measured on the oceans, and sensors are being developed to monitor land surface traffic. Combining interferometry with polarimetric measurements has opened up the possibility of sub-surface imaging, and SAR tomography with a demonstrated ability to estimate vegetation height and measure biomass.

EUSAR has accompanied the worldwide evolution of high-resolution imaging radar, both airborne and space-borne, and has helped to establish an international community of SAR engineers and scientists. As in previous years, EUSAR 2006 provided a forum for exchanging information and discussion on a wide variety of SAR topics representing the latest SAR developments.

On the first day, a series of tutorials was held on subjects covering SAR interferometry, SAR polarimetry, polarimetric SAR interferometry, bistatic SAR and moving target indication and was well attended.

The conference started with a plenary session with keynote speeches by Prof. Achim Bachem, the DLR executive board member responsible for the space and transport programmes, ('The German Space Radar Program: TerraSAR-X and beyond') and by Yves-Louis Desnos, standing in for Dr. Stephen Briggs both from ESA/ESRIN, ('The ESA SAR Missions and their Exploitation for Science and Applications').

Prof. Achim Bachem of DLR speaking at the plenary session of EUSAR 2006

During the three conference days, oral sessions were held in five halls in parallel. Special attention was given to the poster sessions, which were well supported with high-quality contributions and attracted a large enthusiastic audience.

The EUSAR 2006 Industrial Exhibition

An industrial exhibition showing the latest technological and technical developments in the SAR field attracted a number of companies and was well attended by the conference participants.

One feature of EUSAR is the traditional piano concert. In 2006, the concert pianist Isis Moreira, who happens to be the mother of the conference chairman, joined the radar scientist and EUSAR's own piano virtuoso Dr. Richard Klemm.

Isis Moreira and Richard Klemm playing a duet at EUSAR 2006

The conference was closed with the presentation of the awards for best paper, best poster and best student paper. The names of the award winners, as well as the photo gallery can be found under http://www.dlr.de/hr/EUSAR2006/photogallery/.

A Special Issue of the IEEE Transactions on Geoscience and Remote Sensing (TGARS) on Synthetic Aperture Radar, associated with EUSAR 2006, is being prepared for publication in the autumn of this year.

The next EUSAR will take place from 2nd to 5th June 2008 in Friedrichshafen, Germany, on the shores of Lake Constance. You are invited to join the SAR community at EUSAR 2008.

A. Moreira, EUSAR General Chairman
David Hounam, EUSAR Technical Chairman

IVTH INTERNATIONAL WORKSHOP ON ELECTROMAGNETIC WAVE SCATTERING

Gebze, Turkey, 18 - 22 September 2006

The Fourth International Workshop on Electromagnetic Wave Scattering is organized by Gebze Institute of Technology and URSI National Committee of Turkey at TUSSIDE Institute facilities, Gebze, Kocaeli, Turkey on September 18 – 22, 2006.

The first of the series of these workshops was organized in Adana, Turkey at Cukurova University in June 1991. The second one was organized at the Marmara Research Center of TUBITAK (The Scientific and Technological Research Council of Turkey), Gebze, Turkey in September 1995 and the third one was held at Gebze Institute of Technology, Gebze, Turkey in September 2000. Regarding the interest which these meetings had created in the scientific community, it is going to be organized regularly every two years in Turkey.

The aim of this Workshop series is to provide the opportunity to exchange and update information and stimulate discussions on current and future research activities in various aspects of electromagnetic scattering. It is also considered an appropriate platform for encouraging and motivating the young scientists and students where they will find a chance to meet distinguished scientists in the field.

We are thankful for the invaluable contributions of the following distinguished scientists who attended the workshop :

- I. David Abrahams, (University of Manchaster, UK)
- Irsadi Aksun, (Koc University, TURKEY)
- Alinur Buyukaksoy, (Gebze Institute of Technology, TURKEY)

- Ayhan Altintas, (Bilkent University, TURKEY)
- Wolfgang M. Boerner, (UIC-EEC Comm., Sensing&Nav. Lab, USA)
- Olav Breinbjerg, (Technical University of Denmark, DENMARK)
- Weng Cho Chew, (University of Illinois at Urbana-Champaign, USA)
- Ozlem A. Civi, (Middle East Technical University, TURKEY)
- Andreas Danklmayer, (German Aerospace Center, GERMANY)
- Levent Gurel, (Bilkent University, TURKEY)
- Masahiro Hashimoto, (Osaka Electro-Communication University, JAPAN)
- Mithat Idemen, (Yeditepe University, TURKEY)
- Kazuya Kobayashi, (Chuo University, JAPAN)
- Michael Lyalinov, (St. Petersburg University, RUSSIA)
- Raj Mittra, (Pennsylvania State University, USA)
- Frederic Molinet, (Societe MOTHESIM, FRANCE)
- Alex Nosich, (National Academy of Sciences of Ukraine, UKRAINE)
- Yoichi Okuno, (Kumamoto University, JAPAN)
- Andrey Osipov, (German Aerospace Center, GERMANY)
- Prabhakar H. Pathak, (Ohio State University, USA)
- Burak Polat, (Uludag University, TURKEY)
- Alexei Popov, (IZMIRAN, RUSSIA)
- Peter Russer, (Technical University of Munich, GERMANY)
- Jukka Sarvas, (Helsinki University of Technology, FINLAND)
- Levent Sevgi, (Dogus University, TURKEY)
- Lotfollah Shafai, (University of Manitoba, CANADA)
- Hiroshi Shirai, (Chuo University, JAPAN)
- Frank-Olme Speck, (I.S.T. Technical University of Lisbon, PORTUGAL)
- Oleg A. Tretyakov, (Gebze Institute of Technology, TURKEY)
- Yury Tuchkin, (Gebze Institute of Technology, TURKEY)
- Eldar Veliev, (National Academy of Sciences of Ukraine, UKRAINE)
- Ningyan Zhu, (Stuttgart University, GERMANY)

There were 71 presentations where 32 of them were lectures and the rest were poster presentations. The contents of the proceedings are available at the Workshop web site at: http://www.gyte.edu.tr/gytenet/Dosya/102/ews/ews2006/index.htm

Also, two memorial sessions are held which were dedicated to Dr. Ernst Lueneburg. As the collaborators of Dr. Lueneburg, the meorial sessions are chaired by A. Hamit Serbest and Wolfgang M. Boerner; and, Andreas Danklmayer, David Abrahams, Andrey Osipov and Mithat Idemen presented papers.

The Scientific Committee was chaired by Mithat Idemen and the chair of the Organization Committee was Alinur Buyukaksoy. Also, A. Hamit Serbest (Workshop Chairman), Ayhan Altintas (Finance Chairman), Gokhan Uzgoren (Publications Chairman) Eren Erdogan (Social Activities Chairman) and Ali Alkumru with Gokhan Cinar (Secreterial Support) served in the Organizing Committee. Thanks are also due to Ýsmail Hakki Tayyar, Duygu Onal and Ozge Yanaz who did a lot of hard work.

URSI National Committte of Turkey is thankful to the support of TUBITAK. Without their generous help, the congress would not have been that successful. The V.th International Workshop On Electromagnetic Wave Scattering will be held in Antalya, Turkey in September 2008.

REPORT ON THE INTERNATIONAL SCHOOL ON ATMOSPHERIC RADAR
ISAR-NCU

National Central University Chung-Li, Taiwan, 9 - 27 October 2006

Considering the continuing international development of atmosphere and ionosphere radar and space science and the requirement to help newcomers and young students and researchers to get acquainted to these fields, the National Central University in Chung-Li, Taiwan offered the possibility to hold a school on these subjects. The performance of this school is based on the success of earlier schools of this kind, such as for instance those at the International Center for Theoretical Physics in Trieste, where the last one - ISAR-3 - was held in 2002. The idea of these schools bases also on recommendations and resolutions of the international MST (mesosphere-stratosphere-troposphere) radar community, which were adopted at the International Workshops on Technical and Scientific Aspects of MST Radar.

The International School on Atmospheric Radar at the National Central University - ISAR-NCU - was under the main sponsorship of and organization by the National Central University in Chung-Li, Taiwan, with support from the National Science Council and the Ministry of Education of the Republic of China Taiwan. The school was also sponsored by the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) and the International Union of Radio Science (URSI).

The College of Earth Sciences and the Institute of Space Science at the National Central University were the governing local institutions and the school was performed under the local organisation of C.J. Pan with a team of assistants and the international organisation was done by. J. Röttger supported by several lecturers.

The school was announced through the website *www.ss.ncu.edu.tw/~isar* and by individual information of institutes, universities, observatories etc., as well as through URSI and SCOSTEP. More than 80 applications were received to attend ISAR-NCU and after careful scrutinizing these with help of international advisors, 23 students were selected and invited. Unfortunately, due to visa problems, not all invited students could participate. The attending students came from India, Indonesia, Brazil, USA and Taiwan (depending on subjects of lectures 4-8 local students of NCU attended as well). All foreign students received financial support for travel and local accommodation provided by the National Central University, and additional support was also available from SCOSTEP as part of the capacity building program and the from URSI Commission G.

The school ISAR-NCU was held 9 - 27 October 2006 in the well equipped computer laboratory of the Center of Space and Remote Sensing Research at the National Central University in Chung-Li, Taiwan.

The lecture program of ISAR-NCU had been developed well in advance, following the course outline of former schools of this kind. It covered the following main items: Fundamentals of ionospheric and atmospheric radars, principle of the MST radar technique, scattering and reflection processes from the clear and cloudy air, radar antennas, interferometry, transmit-receive systems, radar control, MST radar signal acquisition and pre-processing, radar wind profilers, MST radar meteorology, precipitation scatter, coherent scatter from the ionosphere, ionosonde measurements, GPS occultation methods, a detailed description of the hardware, the operation and data analysis of the Middle and Upper Atmosphere Radar (MUR) in Japan, the Equatorial Atmosphere Radar (EAR) in Indonesia and the upgraded and renovated Chung-Li VHF Radar. To assure satisfactory coverage of the lecture content it had been decided to concentrate mainly on these technical and data analysis topics, and not going too far into the science part of this radar research direction. The latter is intended to be handled more intensely in a future school.

The available networked PC equipment allowed the students to look up some data samples and a few analysis routines for hands-on training. Some time was also set aside to discuss particular questions raised by the students and explain in more details certain methods. Three public lectures were also given on the historical development of the Chung-Li VHF Radar and the Indian National MST Radar in Gadanki, both resulting from the initiatives of the Middle Atmosphere Program (MAP) in the 1980s. In order to give the students the opportunity to train oral presentations and report about their own work a couple of hours were used for nine presentations given by the students.

The lecturers were P.B. Rao (India), K. Reddy (Japan/India), J. Röttger (Germany), M. Yamamoto (Japan), and from Taiwan: A.J. Chen, Y.H. Chu, R.M. Guong, J.Y. Liu, C.J. Pan, and L.C. Tsai.

The opening and closing sessions were attended by the President of the National Central University, Prof. L.C. Lee, who also handed over the awards for successful participation at ISAR-NCU to the students. Present were further the Chancellor of the University System of Taiwan, Prof. C.H. Liu, Vice President Prof. W. Ip, the Dean of the College of Earth Sciences, Prof. B.F. Chao and other high-level representatives of the National Central University. All expressed their high appreciation on the performance of the ISAR at NCU. The President indicated his enthusiasm to strongly support this kind of schools to be held in future at NCU.

Group picture taken before the National Central University in Chung-li, Taiwan

To compensate the hard load to lectures and students, all participants together with guest from the university enjoyed the nicely prepared ice breaker session and the school dinner as well as a full-day tour of Taipei, the nearby capital of Taiwan. Accommodation for students and external lecturers was made available at the very suitable guesthouse of the university, and all participants liked the regular lunch and dinner boxes with typical Chinese food provided by the local organizers.

We appreciated very much the hospitality at NCU, and heard from many students that they enjoyed the school ISAR-NCU and did gain a lot of new knowledge helping them in their studies or research.

Jürgen Röttger
roettger@linmpi.mpg.de

11TH INTERNATIONAL WORKSHOP ON TECHNICAL AND SCIENTIFIC ASPECTS OF MST RADAR - MST11

Tirupati, India, 11 - 15 December 2006

The 11th International Workshop on Technical and Scientific Aspects of MST (Meso-Strato-Troposphere) Radar (here-after referred to as MST11) took place in India from the 11th to 15th of December, 2006, at NARL (National Atmospheric Research Laboratory), Gadanki, and at the Hotel Fortune Kences, Tirupati. Almost 300 delegates attended, with 65 international participants and over 230 Indian attendees. In all 306 oral and poster papers were presented (136 oral and 170 poster), covering a wide range of topics and interests, with only 14 last-minute withdrawals. The workshop was sponsored by NARL, DST (the Indian Department of Science and Technology), RISH (the Research Institute for Sustainable Humanity of Japan), SCOSTEP (specifically through CAWSES), URSI (in particular commissions F and G), Mardoc Inc., and Metek.

The workshop was opened with a large inaugural function at NARL. Participants were treated to a tour of the radar, followed by a welcome by the Director of NARL, Dr. D.N. Rao. This was followed by an address by the Chairman of ISRO (Indian Space Research Organisation), Dr. D.G. Madhavan Nair. Following some words from local government officials, the inaugural address was then given by the President of India, Dr. A.P.J. Abdul Kalam. Dr. Kalam showed a clear understanding of the importance of the atmosphere, and an astute understanding of issues like pollution and global warming. He especially impressed on the audience the important role that the MST community has to play in the future guardianship of the atmosphere. The workshop also included a banquet hosted by Dr. Nair and ISRO, and a cultural event highlighting Indian dance.

The chairmanship of the International Steering Committee was accepted jointly by Professors W. Hocking and T. Tsuda, who took over from Dr. J. Roettger. Dr. Roettger has been a key organizer of almost all of the MST workshops since they began in the early 1980's, and his efforts are greatly appreciated. Members of the International Steering committee were J.L. Chau (Peru), K.S. Gage (USA), W.K. Hocking (Canada), E. Kudeki (USA), D. Narayana Rao (India), I. Reid (Australia), J. Roettger (Germany) and T. Tsuda (Japan), and the main session organizers were A. Muschinski, P. Chilson, J.L. Chau, E. Kudeki, T. Sato, J. Roettger, G. Nastrom, W. Singer, and S. Gurubaran. Many session convenors helped, and their names can be found in the handbook which will be produced from the workshop.

The workshop itself comprised 6 main sessions. A handbook of extended abstracts from the meeting will be produced, as has been the case for all previous MST workshops. A very brief summary of the more significant highlights will be given below.

In addition, a special session was devoted to speeches by retiring and retired members of the MST community, Drs. R. Woodman, S. Fukao and P.B. Rao. Each of these scientists have played critical and long-lasting roles in the MST community, and indeed Dr. Woodman's initial discovery of low altitude fading with the Jicamarca radar in Peru laid the foundations for the science of MST radar. Dr. Fukao is well known as one of the major driving forces behind development of the world-renowned MU radar, and Dr. P.B. Rao was instrumental in encouraging and guiding the early NARL radar development at Gadanki. Each spoke of their own special connections to the MST community, and the talks were well received by both mature and younger members alike.

Several "Young Scientist" awards were handed out at the workshop finale, with each recipient receiving a specially crafted silver medal. Winners were:

> Tomokai Takai (Japan), Smitha V Thampi (India), Susumo Saito (Japan), Manas R. Padhy (India), Tom Grydeland (Norway), Arpit Gupta (India), Koji Nishimura (Japan), Jun-ichi- Furumoto (Japan), Padmavathi Kulkarni (India), Debhashis Nath (India), K.N.Uma (India), K.Kishore Kumar (India), S.Sridhran (India), Simon Peter Alexander (Japan), and Maria Antonita (India).

In all, six main sessions were organized, with titles

- Session I.1. "Radar scattering processes in the atmosphere"
- Session I.2: "Scattering from ionospheric irregularities",
- Session I.3. "Instrumentation, Technical and Signal Processing"

- Session I.4 “Meteorology with Atmospheric Radars.”
- Session I.5. “Mean winds, radar temperatures, waves and tides in the MST region (including CAWSES)”
- Session I.6 “Atmospheric Forcing and Mixing (all levels)”.

Important experimental results included new instruments, such as AMISR (the mobile incoherent scatter radar), as well as progress with new techniques, such as high resolution studies of layers and billows in the atmosphere. Resolutions of a few tens of metres and less are now attainable, both by using short pulses and by employing Frequency Domain Interferometry with Capon’s method (and similar principles). Development of digital receivers is also a major engineering focus for MST studies. The effect of magnetic and electric fields in the upper mesosphere on ambipolar diffusion was also an area of interest, as were Equatorial Spread F echoes and Quasi-periodic echoes. Studies of polar summer and winter echoes were also areas of intense interest. Modelling of turbulence with sophisticated computer algorithms is leading to a better understanding of the scattering mechanisms in the neutral atmosphere, with evidence for stronger reflection from the edges of turbulent layers rather than the middle. The importance of specular spectral spike rejection when using radars to measure turbulence strengths therefore needs to be strongly emphasized.

The aims of CAWSES (Climate And Weather of the Sun-Earth System) was also an important theme of the workshop, with several papers devoted to programs within CAWSES, and many other papers on related issues pertaining to planetary waves, gravity waves, turbulence and coupling. Networks were a major area of discussion, with networks being developed for meteorological, middle atmospheric and ionospheric applications. Information about networks in India and Canada were presented, among others. Meteorological applications, using ST radars in stand-alone mode, as parts of larger networks, and in conjunction with other instruments such as lidars and computer models, were also at the fore. Applications to jet stream studies, precipitation, ozone transport, boundary layer meteorology, and coupling between atmospheric regions, were all presented.

Several resolutions from MST10 were reinforced. These related especially to issues pertaining to young scientists, training and education, which the MST community sees as an area of priority. Successful schools in Peru (second Jicamarca Radar School, 2006) and in Taiwan (International School of Atmospheric Radar ISA-NCU at the National Central University of Taiwan, 2006) were noted. An earlier resolution from MST10 to use calibrated measurements with small, near-identical radars at Arctic and Antarctic sites for inter-comparison of PMSE backscatter cross-sections has already brought useful results.

In all, the workshop provided a forum for discussion of many different aspects of radar theory, science and technical issues. As always, the unique blend of technical, engineering and scientific aspects, which is unique to the MST series, proved to be an excellent combination. The participants were in general well pleased with the workshop, which was well coordinated by the local organizing committee.

A handbook of extended abstract from the workshop will be produced, and a special issue of Annales Geophysicae is in preparation. At the final session of the workshop, it was resolved that the next MST (MST12) would be held in early to mid 2009 in London, Ontario, Canada.

W.K. Hocking, T. Tsuda,
co-chairs of the International Steering Committee
D.N. Rao, Chair, Local Organizing committee.

CONFERENCE ANNOUNCEMENTS

EUROPEAN TEST & TELEMETRY CONFERENCE

Toulouse, France, 12 - 14 June 2007

The two engineering societies AAAF and SEE are organizing the new edition of the European Test & Telemetry Conference ETTC2007. This will be held from, 12 to 14 June 2007 at Pierre Baudis Convention Center in Toulouse - France where the successful ETTC2005 took place.

In June 2005, ETTC 2005 has bought together about 300 participants coming from France, USA, Germany, Belgium, Brazil, Canada, China, Denmark, Spain, Great Britain, Ireland, Israel, Italy, Netherlands and Switzerland.

The high scientific level of the conference program covered the main strategic axis of research and development of test and telemetry domain: flight test instrumentation, acquisition and recording, test data processing, antennas, telemetry spectrum management, electro magnetic compatibility.

This new edition of ETTC2007 will provide the opportunity for scientists and engineers to report and discuss the latest developments in testing methods, especially in aeronautic and space domain. With the associated exhibition, ETTC allows to examine, the scientific, instrumental and operational field of the tests. This year, specific attention will be paid to UAV tests aspects.

You can find more information on
http://www.ettc2007.org

6TH INTERNATIONAL KHARKOV SYMPOSIUM ON PHYSICS AND ENGINEERING OF MICROWAVES, MILLIMETER AND SUBMILLIMETER WAVES (MSMW'07) AND WORKSHOP ON TERAHERTZ TECHNOLOGY (TERATECH'07)

Kharkov, Ukraine, 25 - 30 June 2007

The Sixth International Kharkov Symposium on Physics and Engineering of Microwaves, Millimeter and Submillimeter Waves (MSMW'07) will be held in Kharkov, Ukraine on June 4-9, 2007. Within the symposium, the Workshop on Terahertz Technology (TeraTech'07) will be organized.

The MSMW'07 Symposium and the TeraTech'07 Workshop are organized by the Scientific Council of the National Academy of Sciences of Ukraine on Radio Physics and Microwave Electronics in collaboration with IRE NASU, IRA NASU, IMag NASU and MESU, KhNU, KhNURE, IEEE AP/MTT/ED/AES/GRS/NPS/EMB Societies East Ukraine Joint Chapter, IEEE MTT/ED/AP/CPMT/SSC Societies West Ukraine Joint Chapter, IEEE MTT/ED/COM/CPMT/SSC Societies, the Central Ukraine Joint Chapter and the Ukrainian National URSI Committee.

The sympsia are co-sponsored/technically sponsored by URSI, EuMA, STCU, IEEE MTT and ED Societies. Other sponsors are sought and welcome.

MSMW symposia were held several times in Kharkov since 1978 as regular FSU meetings on mm and submm waves and applications. It became a major event in this area and since 1991 it has been known as the International Kharkov Symposium - MSMW.

Topics

A) Electromagnetic theory and numerical simulation
B) Waves in semiconductors and complex media
C) Microwave superconductivity
D) Wave propagation, radar, remote sensing
E) Signal processing
F) Vacuum sources and amplifiers
G) Quasioptical techniques
H) Antennas
I) Waveguide and integrated circuits
J) Radio astronomy
K) Solid state devices
L) Electromagnetics in nanophysics
M) Terahertz technology
N) Spectroscopy
O) Complex media and new materials
P) Scientific and industrial applications
Q) R-functions, atomic functions, wavelets, fractals
R) Biomedical applications
S) Electromagnetic metrology

The scientific program of the MSMW'07 Symposium and TeraTech'07 Workshop will consist of invited papers, contributed oral and poster presentation. Besides, a series of review lectures will be given by leading scientists for students and young researches.

Chairs and Co-Chairs

Chair MSMW'07

Prof. Vladimir M. Yakovenko

Co-Chairmen MSMW'07 Symposium

Prof. Leonid M. Lytvynenko
Prof. Ilya I. Zalubovsky
Prof. Michail F. Bondarenko

Co-Chairmen TeraTech'07 Workshop

Prof. Anatolii N. Pogorily
Prof. Sergey I. Tarapov

Young Scientist Travel Grants

Young Scientist Travel Grants: similarly to the previous MSMW'07 conferences, modest travel grants are expected to help young scientists from the FSU and Eastern Europe countries to attend the Kharkov symposium. The number and amount of grants will depend on the success of the on-going search for sponsors. Normally grant will cover return train transportation to Kharkov from the city of participant.

Registration

All prospective Symposium participants are requested to complete and return the pre-registration form with the 3-page paper by regular or electronic mail before March 15, 2007. The official invitations will be sent in April 2007 after evaluation of Papers by the Program Committee.

The registration fee for the non-FSU participants is 300 Euro or 370 US$ and covers the cost of the Symposium services, all printed materials, banquet, and refreshments during the MSMW'07.

Social Program

It is expected that social program of the Symposium will offer a city tour, a theater performance, a banquet, a bus tour to the decameter-wavelength radio telescope UTR-2 known as the world largest instrument of this type.

Call for Papers

Authors are asked to submit 3-page electronic manuscripts, both in .doc and .pdf formats, including the text, references, figures, graphs and diagrams. Papers must be written in English. The Proceedings will be prepared directly from the papers supplied by authors, therefore careful preparation is required. Please note that the number of papers accepted by one principal author (the first name in the list of authors) will be limited to three. Detailed information is contained in the attached guidelines and on the Symposium home page in the section "Instruction for Authors": http://www.ire.kharkov.ua/MSMW07/index.html. Invited papers will be given special instructions. As the IEEE technical co-sponsorship is expected, all the authors are requested to fill in the IEEE Copyright form and submit it together with the paper. Post-deadline abstracts will be also considered.

Contact

MSMW'07, IRE NASU,
Ul. Proskura 12, Kharkov, 61085, Ukraine
Ph/Fax: +380 (57) 3152105
E-mail: msmw07@ire.kharkov.ua
http://www.ire.kharkov.ua/MSMW07/index.html

11TH URSI COMMISSION F TRIENNIAL OPEN SYMPOSIUM ON RADIO WAVE PROPAGATION AND REMOTE SENSING

Rio de Janeiro, Brazil, 30 October - 2 November 2007

The series of URSI Commission F International Triennial Open Symposia began in La Baule, France, in 1977. The eleventh, organized by a consortium of Brazilian universities and research institutes (UFF, CETUC-PUC/Rio, IME and INPE) will cover, as the previous ones, the full range of interests of the URSI Commission F.

Topics

Papers are invited on, but not limited to, the following topics relating to radio wave propagation and remote sensing:

- Asymptotic, full wave, numerical and hybrid methods
- Radio meteorology and climatology, including clear air and precipitation effects
- Propagation for fixed and mobile terrestrial and satellite services
- Propagation for position location and navigation services
- Propagation effects of irregular terrain and buildings
- Propagation aspects of interference and frequency management
- Propagation modeling and measurements for MIMO, UWB and FSO applications
- Propagation for mobile and personal access systems
- Over and under water propagation
- Propagation in subsurface and biological media
- Penetration, coupling and shielding of radio waves
- Rough surface and random media scattering
- Propagation and scattering in vegetation
- Channel measurements and modeling
- Transient fields and effects
- Radar, radiometer and optical sensing of land, sea, ice, subsurface and atmosphere
- Applications on environmental and disaster management
- Forestry, agriculture and subsurface topography
- Radar meteorology; Doppler radar, SAR, ISAR, InSAR, PolInSAR
- Propagation aspects of radar remote sensing of buried objects
- Urban remote sensing; Evaluation of orbital and airborne systems
- Remote sensing of atmosphere and ocean
- Propagation and scattering in vegetation - remote sensing applications.

Prospective authors are invited to electronically submit full papers presenting original work not submitted or published elsewhere and formatted according to the authors' guidelines available at the Symposium URL. Papers will be peer-reviewed for scientific quality and presentation quality. Submitted papers will be accepted, conditionally accepted (subject to revision) or rejected. Note that there is no prior submission of abstracts.

Chairs

- **URSI Commission F Chair:** Piotr Sobieski, U.C.L., Belgium
- **URSI Commission F Vice-Chair:** M. Chandra Technische Universitaet Chemnitz, Germany
- **General Chair:** Mauro S. Assis (UFF)

Scientific Program Committee

- Emanoel Costa (CETUC-PUC/Rio, Brazil, Chair, Propagation)
- Luciano Vieira Dutra (INPE, Brazil, Chair, Remote Sensing)
- Bertram Arbesser-Rastburg (ESA-ESTEC, The Netherlands)
- David Fernandes (ITA, Brazil)
- David V. Rogers (CRC, Canada)
- Hajime Suzuki (CSIRO, Australia)
- José Claudio Mura (INPE, Brazil)
- Michael R. Inggs (UCT, South Africa)
- Pascale Dubois-Fernandez (Onera, France)
- Paul McKenna (NTIA/ITS, U.S.A.)
- Robert N. Treuhaft (JPL, U.S.A.)
- Terje Tjelta (Telenor, Norway).
- Maurício H. C. Dias (IME) (Finance Committee)
- Jorge L. Cerqueira (IME) (Local Organization)

Important Deadlines

Submission of First Drafts: 06 July 2007
Notification of Acceptance: 04 September 2007
Submission of Final Papers: 05 October 2007

Contact

Email: ursif@rdc.puc-rio.br
Website: http://wwwusers.rdc.puc-rio.br/ursif

37TH SCIENTIFIC ASSEMBLY OF THE COMMITTEE ON SPACE RESEARCH AND ASSOCIATED EVENTS (COSPAR 2008) "50TH ANNIVERSARY ASSEMBLY"

Montreal, Canada, 13 - 20 July 2008

The 37th COSPAR Scientific Assembly will be held at the Palais des Congrès de Montréal from 13 - 20 July 2008. This Assembly is open to scientists of all nations.

The Scientific Program is chaired by Professor Jean-Pierre St.-Maurice from the University of Saskatchewan, Saskatoon, Canada.

Topics

There will be approximately 85 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)
- Panel on Education
- Special events: 50th anniversary lectures, interdisciplinary lectures, space agency round table, session on "EGY - Towards an Earth and Space Science Commons"

The abstract deadline is Mid-February 2008. The papers will be published in "Advances in Space Research", a fully refereed journal.

Contact

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http://www.cospar2008.org/ or
http://www.cospar-assembly.org

URSI CONFERENCE CALENDAR

May 2007

12th Microcoll - Colloquium on Microwave Communications
Budapest, Hungary, 14-16 May 2007
Contact : Prof. L. Nagy, BUTE, Dept. of Broadband Communications, H-1111 Goldmann Gy. tér 3, Budapest, Hungary, fax +36 1-463 3289, E-mail : nagy@mht.bme.hu, Web : http://www.diamond-congress.hu/mow2007

June 2007

ETTC'07 - European Test and Telemetry Conference 2007
Toulouse, France, 12-14 June 2007
cf. Announcement in the Radio Science Bulletin of March 2007, p. 55.
Contact : AAAF - ETTC 2007 , 23, avenue Edouard Belin - 31400 Toulouse - France , Tel: 33 5 62 17 52 80 , Fax: 33 5 62 17 52 81 , Email : ettc2007@aol.com , S.E.E - ETTC 2007, 17 rue Hamelin 75783 Paris Cedex 16 – France, Tel : 33 1 56 90 37 06, Fax : 33 1 56 90 37 08, email : ettc2007@see.asso.fr Web: http://www.ettc2007.org/

EMC Workshop 2007
Paris, France, 14-15 June 2007
Contact : Prof. Martine Liénard, Université de Lille, USTL, TELICE/IEMN - Bat. P3, 59655 Villeneuve d'Ascq Cedex, FRANCE, Phone: + 33 (0)3 20 33 71 34, Fax: + 33 (0)3 20 33 72 07, e-mail : emcworkshop@univ-lille1.fr, Web : http://emcworkshop.univ-lille1.fr/

MSMW'07 - Sixth International Kharkov Symposium on Physics and Engineering of Microwaves, Millimeter and Submillimetre Waces + TeraTech'07
Kharkov, Ukraine, 25-30 June 2007
cf. Announcement in the Radio Science Bulletin of March 2007, p. 56.
Contact : MSMW'07, IRE NASU, Ul. Proskury 12, Kharkov, 61085, Ukraine, Phone: +38 (057) 3150006 , Fax: +38 (057) 3152105, E-mail: msmw07@ire.kharkov.ua, http://www.ire.kharkov.ua/MSMW07/index.html

EMC'07 - International Symposium on Electromagnetic Compatibility and EM Ecology
St. Petersburg, Russia, 26-29 June 2007
cf. Announcement in the Radio Science Bulletin of September 2006, p. 50.
Contact : Discone-Centre Ltd., St. Petersburg State Electrotechnical University - LETI, Tel. +7 812-234-4840, Fax +7 812-234-4681, E-mail : discone@mail.wplus.net , Web : www.eltech.ru/emc

July 2007

IRI/COST296 Workshop on Ionosphere Modeling, Forcing and Telecommunications
Prague, Czech Republic, 10-14 July 2007
Contact : Dr. Jan Lastovicka, Institute of Atmospheric Physics, Acad. Sci. Czech Republic, Bocni II, 1401a, 14131 Prague 4, Czech Republic, Fax +420 2727 63745, jla@ufa.cas.cz

URSI CNC/USNC North American Radio Science Meeting
Ottawa, ON, Canada, 22-26 July 2007
Contact : Dr. Yahia M.M. Antar, (CNC Chair), Email: antar-y@rmc.ca , Dr. George Uslenghi, (USNC Chair), Email: uslenghi@uic.edu, Web : http://ursi2007.ee.umanitoba.ca

EMTS 2007 - URSI Commission B EMT-Symposium
Ottawa, ON, Canada, 26-28 July 2007
cf. Announcement in the Radio Science Bulletin of December 2006, p. 77.
Contact : Prof. Lot Shafai, Chair Commission B, Dept. of Electrical and Computer Engineering, University of Manitoba, 75 Chancellors Circle, Winnipeg, MB, Canada R3T 5V6, Fax (204) 269 - 0381, E-mail : shafai@ee.umanitoba.ca , Web : http://emts2007.ee.umanitoba.ca

International Symposium on Signals, Systems, and Electronics (ISSSE 2007)
Montreal, Canada, 30 July - 2 August 2007
cf. Announcement in the Radio Science Bulletin of December 2006, 78.
Contact: Prof. Ke Wu, Director of Poly-Grames Research Center, Ecole Polytechnique, C. P. 6079, Succ. Centre-Ville, Montreal, Quebec, Canada H3C 3A7, Tel: +1 (514) 340-4711 ext. 5991, Fax: +1 (514) 340-5892, E-mail: ke.wu@polymtl.ca or ke.wu@ieee.org

August 2007

Rarotonga Energetic Particle Workshop 2007
Rarotonga (Cook Islands), 5-10 August 2007
Contact : Dr. Craig J. Rodger, Department of Physics, University of Otago, P.O. Box 56, Dunedin, New Zealand, Fax +64 3 479 0964, crodger@physics.otago.ac.nz , Web : http://www.physics.otago.ac.nz/space/REPW2007_Home_Page.htm

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

September 2007

International Symposium on Radio Systems and Space Plasma
Sofia, Bulgaria, on 2-5 September 2007
cf. Announcement in the Radio Science Bulletin of December 2006, p. 79.
Contact : Prof. B. Shishkov, Head of Telecommunication Dept., Institute of Mathematics & Informatics, Bulgarian Academy of Sciences, Acad. G. Bonchev Str., Bl. 8, Sofia 1113, Bulgaria, fax: ++359 2 971 3649, e-mail: bshishkov@math.bas.bg, Web : http://www.math.bas.bg/isrssp/

International Conference on Electromagnetics in Advanced Applications (ICEAA 07)
Torino, Italy, 17 - 21 September 2007
cf. Announcement in the Radio Science Bulletin of December 2006, p. 79.
Contact: Prof. Roberto D. Graglia, Chair of ICEAA Organizing Committee, Dipartimento di Elettronica, Politecnico di Torino, Corso Duca degli Abruzzi, 24, 10129 Torino, Italy, E-mail: roberto.graglia@polito.it or Prof. Piergiorgio L. E. Uslenghi, Chair of ICEAA Scientific Committee, Department of ECE (MC 154), University of Illinois at Chicago, 851 South Morgan Street, Chicago, IL 60607, USA, E-mail: uslenghi@uic.edu.

EMC Zürich 2007
München, Germany, 24-28 September 2007
Contact : Prof. Dr. P. Russer, Symposium President, TU Munich, Germany and Prof. Dr. R. Vahldieck, General Chairman, ETH Zürich, IFH, Switzerland, Tel: +41 44 632 2951, Fax: +41 44 632 1198 , e-mail: info@emczurich.ethz.ch , http://www.emc-zurich.ch/

October 2007

From Planets to Dark Energy: the Modern Radio Universe
Manchester, UK, 1-5 October 2007
cf. Announcement in the Radio Science Bulletin of December 2006, p. 80.
Contact : Prof. Ph. Diamond, Jodrell Bank Observatory, University of Manchester, Macclesfield, Cheshire SK11 9DL, UK, fax +44 1477-572618, E-mail : pdiamond@jb.man.ac.uk , majordomo@jb.man.ac.uk , Web : http://www.jb.man.ac.uk/mru2007/

Scientific and Fundamental Aspects of the Galileo Programme
Toulouse, France, 2-4 October 2007
cf. Announcement in the Radio Science Bulletin of December 2006, p. 81.
Contact : Dr. Bertram Arbesser-Rastburg, ESA-ESTEC, TEC-EEP, Postbus 299, NL-2200 AG Noordwijk, the Netherlands, fax +31 71 565-4999, Organisation Committee: Martine.Segur@anae.fr, Scientific Committee: Clovis.de.Matos@esa.int, Web : www.congrex.nl/07a06

Metamaterials 2007 - The First International Congress on Advanced Electromagnetic Materials for Microwaves and Optics
Rome, Italy, 22-26 October 2007
cf. Announcement in the Radio Science Bulletin of December 2006, p. 81.
Contact : Dr. Said Zouhdi, Electrical Engineering, University Pierre et Marie Curie, Paris, France + Laboratoire de Genie Electrique de Paris LGEP-Supelec, Fax : + 33 1 69 41 83 18, E-mail : sz@ccr.jussieu.fr

11th URSI Commission F Triennial Open Symposium on Radio Wave Propagation and Remote Sensing
Rio de Janeiro, Brazil, 30 October - 2 November 2007
cf. Announcement in the RAdio Science BUlletin of March 2007, p. 57.
Contact : Dr. Emanoel Costa, CETUC-PUC/Rio, Brazil (Chair, Propagation), Luciano Vieira Dutra, INPE, Brazil (Chair, Remote Sensing), Web: http://wwwusers.rdc.puc-rio.br/ursif/

November 2007

APSAR 2007 - Asia-Pacific Conference on Synthetic Aperture Radar
Huangshan city, Anhui province, China, 5-10 November 2007
Contact : Mr. Mengqi Zhou, Chinese Institute of Electronics, P.O. Box 165, 100036 Beijing, China, Phone : +86 10-6816 0825, Fax : +86 10-6828 3458, E-mail : mqzhou@public.bta.net.cn , Web: http://www.cie-china.org/APSAR2007/index.htm

EuCAP 2007 - The Second European Conference on Antennas and Propagation
Edinburgh, United Kingdom, 11-16 November 2007
Contact : The Institution of Engineering and Technology, Paul Newell / Simon Blows / Emily Woodman, Event Services, Michael Faraday House, Six Hills Way, Stevenage, Hertfordshire SG1 2AY, UK, Tel: +44 1438 765648/ 765653, Fax: +44 1438 765659, Email: eucap@ietevents.org, http://www.eucap2007.org/

December 2007

APMC 2007 - 2007 Asia-Pacific Microwave Conference
Bangkok, Thailand, 11-14 December 2007
cf. Announcement in the Radio Science Bulletin of September 2006, p. 51.
Contact : Dr. Chuwong Phongcharoenpanich, General Secretary of APMC 2007, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand, E-mail:kpchuwon@kmitl.ac.th, Web:http://www.apmc2007.org/

February 2008

ICRS 2008 - International Conference on Radio Science
Jodhpur, India, 25-29 February 2008
Contact : Prof. O.P.N. Calla, Director ICRS, OM-NIWAS, A-23 Shastri Nagar, Jodhpur 342003, Rajasthan, India, Fax +91 291-2626166, E-mail : opncalla@yahoo.co.in , E-mail : http://radioscience.org/default.html

May 2008

IES2008 - 12th International Ionospheric Effects Symposium
Alexandria, Virginia, USA, 6-8 May 2008
Contact : JMG Associates Ltd., IES Symposium Managers, 8310 Lilac Lane, Alexandria VA 22308, USA, Fax: +1-703-360-3954, Web : http://www.ies2008.com/index.html

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

July 2008

COSPAR 2008 - 37th Scientific Assembly of the Committee on Space Research and Associated Events "50th Anniversary Assembly"
Montreal, Canada, 13 - 20 July 2008
cf. Announcement in the Radio Science Bulletin of March 2007, p. 58.
Contact : COSPAR Secretariat, c/o CNES, 2 place Maurice Quentin, 75039 Paris Cedex 01, France, Tel: +33 1 44 76 75 10, Fax: +33 1 44 76 74 37, E-mail : cospar@cosparhq.cnes.fr, Web : http://www.cospar2008.org

EUROEM 2008 - European Electromagnetics
Lausanne, Switzerland, 21-25 July 2008
Contact : EUROEM'08, EPFL-STI- LRE, Station 11, CH-1015 Lausanne, Switzerland, Tel : +41-21-693 26 20, Fax : +41-21-693 46 62, E-mail: information@euroem.org, Web : http://www.euroem.org

August 2008

URSI GA08 - XXIXth URSI General Assembly
Chicago, IL, USA, 9-16 August 2008
Contact : URSI Secretariat, c/o INTEC, Ghent University, Sint-Pietersnieuwstraat 41, B-9000 Ghent, Belgium, Tel. : +32 9 264 3320, Fax : +32 9 264 4288, E-mail : info@ursi.org

An up-to-date version of this Conference Calendar, with links to various conference web sites can be found at www.ursi.org/Calandar of supported meetings

Please note that the Radio Science Bulletin is freely available on the web. From the September 2002 issue onwards, it is possible to download our magazine (in .pdf format) from http://www.ursi.org/RSB.htm

News from the URSI Community

NEWS FROM THE MEMBER COMMITTEES

FRANCE

Médaille du CNFRS

La Médaille du Comité National Français de Radioélectricité (CNFRS) section française de l'Union Radio Scientifique Internationale (URSI) a été décernée le 20 mars 2007 à Bernard Veyret. Le CNFRS souhaite ainsi souligner l'importance des contributions de Bernard Veyret au développement des connaissances en bioélectromagnétisme, à la compréhension et à la caractérisation des interactions entre champs électromagnétiques et le vivant, et comme animateur des communautés scientifiques de ces mêmes domains.

Cette médaille est "destinée à honorer des personnes qui ont œuvré pour le renom de la Science en Radioélectricité et/ou participé d'une manière très significative à la vie et au renom du CNFRS/URSI.

Bernard Veyret, né en 1950, ingénieur physicien de l'ESPCI, a d'abord été chercheur en photochimie à Boston pendant trois ans, puis enseignant au Maroc pendant deux ans. Il a, en 1979, rejoint le Laboratoire de photochimie et photochimie moleculaire de Bordeaux dirigé par Jacques Joussot-Dubien, pour travailler sur la chimie troposphérique.

A la suite d'un stage postdoctoral de la Royal society au department de Chimie de l'Université de Cambridge en Angleterre, il a développé son activité de recherché au Laboratoire de Physique des Interactions Ondes-Matière (PIOM) à Bordeaux, dans l'équipe de bioélectromagnétisme, qu'il anime depuis 1985. Il est actuellement Directeur de recherche au CNRS et Directeur d'étude de l'Ecole Pratique des Hautes Etudes. Lors d'une année sabbatique à Rome en 2005, il a collaboré avec le groupe de bioélectromagnétisme du département d'électronique de l'Université La Sapienza.

Ik fut en 1989 l'un des fondateur de l'Association Européenne de Bioélectromagnétisme (EBEA) qui va organiser à Bordeaux son 8$^{\text{ème}}$ congrès en avril 2007. Bernard Veyret a coordonné le programme français COMOBIO du RNRT et le programme européen Perform B. Il a participé à la redaction de nombreux rapports européens et français sur le theme "champs électromagnétiques et santé".

Ik fut Vice-président et Président de la Commission K (Electromagnétisme en biologie et médicine) du CNFRS puis Président de la commission K de l'URSI de 2002 à 2005, jusqu'à l'assemblée générale de New Delhi. Il est actuellement coordinateur de la redaction du Livre Blanc de l'URSI sur "Communications sans fil et santé".

Bernard Veyret appartient à l'ICNIRP (International Commission on Non Ionizing Radiation Protection) depuis 2000; il fut responsable du comité "Biologie" attaché à cette commission.

Ik est l'auteur de quelques 75 articles dans des revues internationales dont la moité portent sur le bioélectromagnétisme.

TURKEY

3rd National Congress URSI-Turkey 2006

Haceteppe University, Beytepe, Ankara, Turkey, 6 - 8 September 2006

The Third National Congress of URSI-Turkey National Commitee took place at Hacettepe University, Ankara, Turkey on September 6-8, 2006. The chair of the organization Committee was Prof. Erdem Yazgan. The members of local organization commitee were, Assoc. Prof. Dr. Birsen Saka Tanatar, Research Assistants Volkan Akan, Gökþen Turgut Þanþal, Aslý Er Akan and Iþýl Birinci. The constant interest and generous support of the Turkish National Committee Chair, Prof. Hamit Serbest is worth mentioning. The aim of the Congress was to bring together Turkish speaking scientist and engineers in the URSI related areas, and to facilitate the exchange of ideas and information. Another aim was to encourage and motivate the young scientists and students in URSI topics.

Outstanding speakers were invited to cover a broad range of radioscience topics. Their presentations covered up-to-date research topics. The invited speakers and their presentations were:

- Prof. Madhavan Swaminathan, Georgia Institute of Technology, USA, “Mixed Signal Integration in Multilayered Organic Substrates”.
- Prof. Louis Bertel, University of Rennes, France, “Antenna and Propagation Effects on HF Ionospheric Studies and Applications”.
- Prof. Wolfgang Keydel, Kepler University, Germany, “German Space-Borne SAR Systems to be Launched in 2006 and Beyond”.
- Prof. Alinur Buyukaksoy, Gebze Institute of Technology, Turkey, “Plane Wave Diffraction by Impedance Loaded Parallel Plate Waveguides”.
- Prof. Ekmel Ozbay, Bilkent University, Turkey, “Observation of Negative Refraction and Subwavelength Focusing in Metamaterails Radio Frequency Micro-Electromechanical Systems”
- Prof. Yurdanur Tulunay, Middle East Technical University, Turkey, “International Geophysical Year (IGY) is the 50 Years of Exploration of Near Earth Space-IHY: Applications on Medium, Radio Science Technology”.
- Prof. Irsadi Aksun, Koç University, Turkey, “New Developments in Hybrid Solution of Moment Methods and Closed-Form Green’s Functions”.
- Prof. Tayfun Akin, Middle East Technical University, Turkey, “Radio Frequency Micro Electro mechanical Systems (RF MEMS)”.
- Prof. Ayhan Altintas, Bilkent University, Turkey, “Fast Methods and Applications for the Scattering and Propagation Over Large Scale Rough Surfaces”.

There were 326 participants with 203 presentations. The presentations were given in the four parallel sessions of the three days of the Congress. The proceeding is available at the URSI Turkey web site at: http://www.ursi.org.tr/ucuncukongre.htm.

Another session was arranged by the firms for giving information about new equipments and the use of software programs for numerical computations in electromagnetics, microwaves and telecommunication applications. A small exhibition was also organized by the firms Spark, Aktif-Neser and Rohde & Schwarz.

IEEE Turkey Section and IEEE AP/MTT/EMC/ED Chapter supported the organization of the student paper contest. Seven students were awarded as “selected student papers”. They were K.O. Ozkan (Middle East Technical University), E.Yigit (Mersin University), O. Ozgun (Middle East Technical University), T. Malas (Bilkent University), H. Yigitler (Middle East Technical University), T.K.Yaþar (Middle East Technical University) and S. Deger (Hacettepe University).

URSI Turkey National Committe thanks to the support of Hacettepe University, TUBITAK, ASELSAN, HAVELSAN, SPARK, AKTIF NESER, ROHDE & SCHWARZ, SISTAÞ, CST, UDEA and The Chamber of Electrical Engineers for their generous sponshorpship.

The next National Congress of the URSI National Committee of Turkey will be held at Akdeniz University in Antalya in September 2008.

BOOKS PUBLISHED BY URSI RADIOSCIENTISTS

Inverse Problems in Electric Circuits and Electromagnetics

Series: Mathematical and Analytical Techniques with Applications to Engineering

By N.V. Korovkin,V.L. Chechurin, and M. Hayakawa, Springer, 2007, 332 pp, Hardcover,
ISBN 0-387-33524-2

About this book

Inverse Problems in Electric Circuits and Electromagnetics discusses methods of solution of so-called inverse problems that are often encountered in electrical engineering, electronics, and electro-physics. The objective of solution of such inverse problems is to assure that the manufacturing of devices is optimal according to specified criteria. Approaches stated in the book show ways of making devices that ensure best electromagnetic performance, minimal weight, thermal emission, etc. These approaches can be applied to the modernization of existing devices, as well as to improve their technical features or to extend their operational life.

This text treats important new methods in inverse problems in electromagnetics. Inverse problems such as synthesis, diagnostics, fault detection, and identification are becoming some of the most important subjects in the field, because of the significant practical applications to electric circuits and electromagnetics.

This book introduces the recent achievements in mathematics and computing, while we focus on an approach to inverse problems that provides numerical solutions. The text systematically supplies descriptions of the most important practical inverse problems and the methods to solve them, thereby providing the reader with the best application for these intuitive processes. Also included are descriptions of the properties of inverse problems and known methods of their solution, as well as the practical implementation of these methods in electric-circuit theory and electromagnetic-field theory.

Basic attention is given to clarity and simplicity. This book is comprehensive enough for students that have taken a course in electrical engineering or in electronics. All approaches and methods of solution of inverse problems are supplied by numerous examples. These examples are educational, in addition to existing solid examples for engineering problems important for practice. The authors have planned this book for students of electrical and electronic engineering, electro-physics, and other specialties who are training for practical work, as well as for specialists already working in the field.

Table of Contents

About the Authors

Drs. Korovkin and Chechurin work at St. Petersburg State Polytechnical University, St. Petersburg, Russia. Dr. M. Hayakawa works at the University of Electro-Communications, Chofu, Tokyo, Japan. He was the Japanese URSI Commission E Chair and was URSI Commission E Chair (1996-1999). He is Chair of one of the working groups of Commission E.

Resonances in the Earth-Ionosphere Cavity

Series: Modern Approaches in Geophysics

By A. P. Nickolaenko and M. Hayakawa, Kluwer Academic Publishers, 381 pp., Hardcopy, 2002,
ISBN 1-4020-0754-X

About this Book

This book deals with the theoretical and experimental aspects of electromagnetic resonance phenomena in the Earth-ionosphere cavity in the ELF and VLF ranges. This book describes a general approach to physical problems, ways to solve them, and properties of the solutions obtained. Attention is given to the discussion and interpretation of formal and experimental data and their links to global atmospheric conditions, such as the dynamics of global thunderstorm activity, variations of the effective height of the lower ionosphere, etc.

The ELF Schumann resonance, which is a resonance phenomenon in the Earth-ionosphere cavity, is related to worldwide thunderstorm activity and also to global properties of the lower ionosphere. Recently, this Schumann resonance has been suggested as a monitoring tool for global warming. Transverse resonance is predominantly the local phenomenon containing information on the local height and conductivity of the lower ionosphere and on nearby thunderstorm activity.

Transient events recently found in ELF-VLF radio propagation are also treated. These are natural pulsed radio signals and/or abrupt changes of manmade VLF radio signals. The ELF transients associated with cloud-to-ionosphere discharges (red sprites, blue jets, etc.) are discussed, and clarification of the underlying physical ideas and their practical applications to pioneering results achieved in the recent field are emphasized.

Table of Contents

About the Authors

A. P. Nickolaenko works at Usikov Institute of Radiophysics and Electronics, Kharkov, Ukraine. He is a co-Chair of an URSI Commission E working group. M. Hayakawa works at the University of Electro-Communications, Chofu, Tokyo, Japan. He was the Japanese URSI Commission E Chair and was the URSI Commission E Chair (1996-1999), and he is also a co-Chair of a Commission E working group.

[The above announcements were provided by the publishers.]

In Memoriam

Tor Hagfors
1930 - 2007

Prof. Tor Hagfors passed away on January 17, 2007, during a visit to the Arecibo Observatory in Puerto Rico.

Born in 1930 in Oslo, he received his education in Oslo and Trondheim, finishing his studies with a PhD in Physics from the University of Oslo in 1959. His first employment was with the Norwegian Defense Research Establishment from 1955 to 1963, interrupted by a position as Research Associate at Stanford University in 1959/60.

From 1963 to 1967 and again from 1969 to 1971, he was a staff member of the MIT Lincoln Laboratory. From 1967-1969, he served as Director of the Jicamarca Radio Observatory near Lima, Peru, and from 1971 to 1973, as Director of Operations of the Arecibo Observatory in Puerto Rico. He subsequently went back to Norway, accepting a position as Professor of Electrical Engineering at the Norwegian University of Science and Technology in Trondheim, where he stayed until 1982. During this time, from 1976 until 1982, he was also the founding Director of the European Incoherent Scatter Association (EISCAT) in Kiruna, Sweden. He next was a Professor of both Astronomy and Electrical Engineering at Cornell University in Ithaca, New York, until 1992, and was simultaneously Director of the National Astronomy and Ionosphere Center (NAIC), which manages the Arecibo Observatory. In addition, during this period (1989/09) he was awarded a senior Humboldt Fellowship, which he spent at the Max-Planck-Institut für Aeronomie in Lindau, Germany. Having already served as a member of the Scientific Advisory Committee of this institute since 1976, in 1992 he accepted a call to be a Director of the Max-Planck-Institut für Aeronomie, where he stayed until his retirement at the end of 1998. Simultaneously, he was a Professor at the University of Oslo. After his retirement, he kept scientifically active not only at the renamed Max-Planck-Institut für Sonnensystemforschung (Solar System Research), but also as a Guest Professor at the University of Tromsø/Norway, at the University of Nagoya/Japan, and at the University of Lancaster/UK.

His scientific interests focused from the very beginning on the scattering of radio waves from magnetized plasmas, and also from random rough surfaces, including polarization effects. The latter result, published in an often-cited paper in 1964, has come to be known as the “Hagfors Scattering Law,” laying the foundations for radio-astronomical studies of the surfaces of the moon and the planets. His plasma-physics research covered a wide range of ionospheric topics, such as the foundations of the incoherent-scatter theory; radar scattering from irregularities in the auroral and the equatorial electrojet; the theory and practice of modification of the ionosphere by powerful radio waves, including the application of a novel chirp technique; the observation of Langmuir waves in natural and HF-modified plasmas; advanced riometer techniques; and observations of optical emissions from aurora. Among his achievements in radio astronomy were the determination of the effective dielectric constant of the surface of the moon at 50 MHz, radar observations of the surface of Venus, the mapping of rapidly rotating planetary bodies, the application of lunar reflections for very-long-baseline interferometry, studies of the scattering from the Galilean satellites of Jupiter, studies of the interior of comets and asteroids by radio methods, and, recently, the search for water on Mars by means of a long-wavelength radar on the Mars Express spacecraft. His success as a radio scientist was based not only on his profound knowledge of the underlying physics, but also on his engineering skills and experience. His numerous scientific achievements were published in approximately 170 papers.

Besides being a brilliant and ingenious scientist, he was also an inspiring and gifted teacher, lecturing on information theory, plasma physics, radio astronomy, and also on technical subjects such as radio techniques and antenna design. In his various directorships, he displayed exceptional organizational and diplomatic skills. As the founding Director of EISCAT, he raised the necessary funds for the construction and operation of the facility, and he established the framework of rules necessary to operate the organization with six European research councils. As NAIC Director, he developed the concepts for upgrading the Arecibo antenna with a new and complex Gregorian feed system, and a noise-reducing fence that shields the antenna from thermal radiation from the ground. He obtained the funds for this major upgrade from the US National Science Foundation and NASA. During his time at the MPI für Aeronomie, he developed concepts that ensured the survival of the Institute in the face of threats of closure due to the need for the Max Planck Society to establish new institutes in the reunited East Germany.

His scientific honors were numerous and cannot all be listed here. Among the most prestigious were the URSI Van der Pol Gold Medal, received in 1987; the Humboldt Society Senior Scientist Award, 1989; membership of the Royal Norwegian Academy of Science and Letters, 1996; Associate Membership of the Royal Astronomical Society, 1998; the EISCAT Sir Granville Beynon Medal, 2002; and the Doctor honoris causa of the University of Oulu, 2002, and of the University of Tromsø, 2003. The asteroid 1985 VDI was named “Hagfors” in 2000.

Although he was a highly acclaimed scientist, he remained a modest, unselfish, and friendly person: everyone was at ease with him. He liked gatherings and social contacts, and he was a terrific host. Parties at the various institutions where he served were often memorable.

We have lost an outstanding scientist, an admirable colleague, and a sincere friend of many of us.

Kristian Schlegel
E-mail: schlegel@linmpi.mpg.de

Wireless Networks

The journal of mobile communication, computation and information

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Aims & Scope:
The wireless communication revolution is bringing fundamental changes to data networking, telecommunication, and is making integrated networks a reality. By freeing the user from the cord, personal communications networks, wireless LAN's, mobile radio networks and cellular systems, harbor the promise of fully distributed mobile computing and communications, any time, anywhere. Numerous wireless services are also maturing and are poised to change the way and scope of communication. WINET focuses on the networking and user aspects of this field. It provides a single common and global forum for archival value contributions documenting these fast growing areas of interest. The journal publishes refereed articles dealing with research, experience and management issues of wireless networks. Its aim is to allow the reader to benefit from experience, problems and solutions described. Regularly addressed issues include: Network architectures for Personal Communications Systems, wireless LAN's, radio , tactical and other wireless networks, design and analysis of protocols, network management and network performance, network services and service integration, nomadic computing, internetworking with cable and other wireless networks, standardization and regulatory issues, specific system descriptions, applications and user interface, and enabling technologies for wireless networks.

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The Journal of Atmospheric and Solar-Terrestrial Physics

SPECIAL OFFER TO URSI RADIOSCIENTISTS

AIMS AND SCOPE

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

Content

The *Radio Science Bulletin* is published four times per year by the Radio Science Press on behalf of URSI, the International Union of Radio Science. The content of the *Bulletin* falls into three categories: peer-reviewed scientific papers, correspondence items (short technical notes, letters to the editor, reports on meetings, and reviews), and general and administrative information issued by the URSI Secretariat. Scientific papers may be invited (such as papers in the *Reviews of Radio Science* series, from the Commissions of URSI) or contributed. Papers may include original contributions, but should preferably also be of a sufficiently tutorial or review nature to be of interest to a wide range of radio scientists. The *Radio Science Bulletin* is indexed and abstracted by INSPEC.

Scientific papers are subjected to peer review. The content should be original and should not duplicate information or material that has been previously published (if use is made of previously published material, this must be identified to the Editor at the time of submission). Submission of a manuscript constitutes an implicit statement by the author(s) that it has not been submitted, accepted for publication, published, or copyrighted elsewhere, unless stated differently by the author(s) at time of submission. Accepted material will not be returned unless requested by the author(s) at time of submission.

Submissions

Material submitted for publication in the scientific section of the *Bulletin* should be addressed to the Editor, whereas administrative material is handled directly with the Secretariat. Submission in electronic format according to the instructions below is preferred. There are typically no page charges for contributions following the guidelines. No free reprints are provided.

Style and Format

There are no set limits on the length of papers, but they typically range from three to 15 published pages including figures. The official languages of URSI are French and English: contributions in either language are acceptable. No specific style for the manuscript is required as the final layout of the material is done by the URSI Secretariat. Manuscripts should generally be prepared in one column for printing on one side of the paper, with as little use of automatic formatting features of word processors as possible. A complete style guide for the *Reviews of Radio Science* can be downloaded from http://www.ips.gov.au/IPSHosted/NCRS/reviews/. The style instructions in this can be followed for all other *Bulletin* contributions, as well. The name, affiliation, address, telephone and fax numbers, and e-mail address for all authors must be included with all submissions.

All papers accepted for publication are subject to editing to provide uniformity of style and clarity of language. The publication schedule does not usually permit providing galleys to the author.

Figure captions should be on a separate page in proper style; see the above guide or any issue for examples. All lettering on figures must be of sufficient size to be at least 9 pt in size after reduction to column width. Each illustration should be identified on the back or at the bottom of the sheet with the figure number and name of author(s). If possible, the figures should also be provided in electronic format. TIF is preferred, although other formats are possible as well: please contact the Editor. Electronic versions of figures *must* be of sufficient resolution to permit good quality in print. As a rough guideline, when sized to column width, line art should have a minimum resolution of 300 dpi; color photographs should have a minimum resolution of 150 dpi with a color depth of 24 bits. 72 dpi images intended for the Web are generally *not* acceptable. Contact the Editor for further information.

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Review Process

The review process usually requires about three months. Authors may be asked to modify the manuscript if it is not accepted in its original form. The elapsed time between receipt of a manuscript and publication is usually less than twelve months.

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