The Radio Science Bulletin

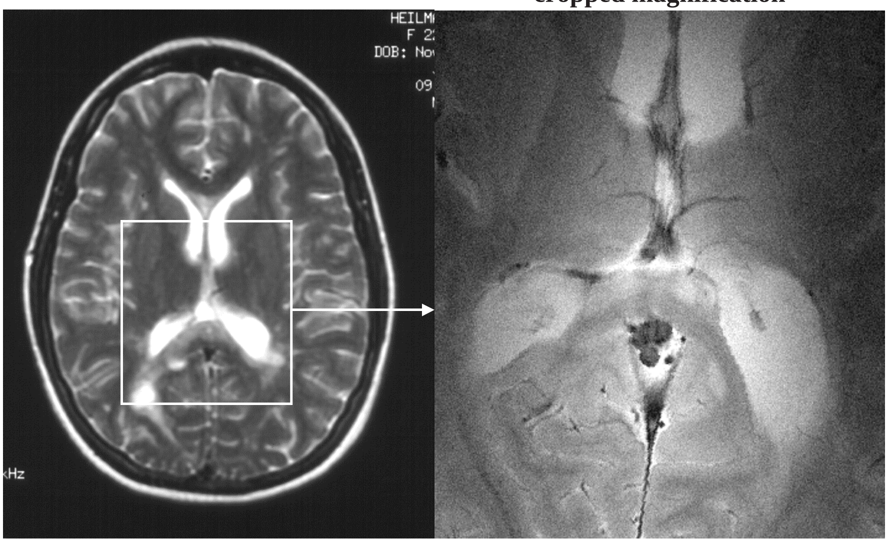
ISSN 1024-4530

INTERNATIONAL
UNION OF
RADIO SCIENCE

UNION
RADIO-SCIENTIFIQUE
INTERNATIONALE

1.5 T Fast Spin Echo T2

8 T Gradient Echo 1024 cropped magnification



No 303
December 2002

Publié avec l'aide financière de l'ICSU
URSI, c/o Ghent University (INTEC)
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Contents

*Front cover: Figure 4 from "High-Field Human MRI: Clinical Applications and Safety Aspects"**(Continued on page 4)*

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

Editorial

We're On the Web!

Thanks to the efforts of our Production Editors, Inge Lievens and Inge Heleu (who is also our URSI Webmaster), the *Radio Science Bulletin* has been available on the Web since the September, 2002, issue. You can download each issue as it becomes available in PDF format (and the issues will be archived there, beginning with the September issue). One of the many advantages of making the *Bulletin* available in this form is that color figures can be viewed in color. Visit http://www.ursi.org/RSB.htm, or follow the "Latest News" link from the URSI homepage at http://www.ursi.org (and also note the new, simpler URL for the URSI homepage).

By the way, if you aren't using the latest version of Adobe *Acrobat Reader* (version 5.1), I strongly suggest you upgrade. You can do so without cost at http://www.adobe.com. In particular, version 5 supports substantially improved indexing and searching capabilities compared to previous versions.

What's In this Issue

As discussed below, our efforts to try to increase the technical content of the *Radio Science Bulletin* are showing more results. We have four papers for you this time, and all should be interesting to a good cross section of our URSI community.

Eight Tesla (8T) is a very strong magnetic field. When used as the primary magnetic field for human magnetic-resonance imaging (MRI), it opens up a whole new range of potential imaging capabilities. For example, the much higher resolution of such images (compared with images obtained at lower field values) permits studying the occurrence and formation of the plaques in brain matter that are associated with multiple sclerosis. Images that provide much improved diagnosis and treatment guidance for brain tumors become possible. These and other applications are described by Alayar Kangarlu and D. W. Chakeres in their paper on high-field human MRI. The exposure of humans to such high magnetic fields also raises a number of potential questions about safety. These issues are also addressed in the paper. The results are exciting and interesting. This paper was the Commission K tutorial lecture presented at the Maastricht General Assembly.

Inverse scattering is the process of determining the characteristics of an object from measurements of the fields scattered by the object. In general, such problems are inherently ill-posed mathematically, and many real-world applications are nonlinear. There are also problems with uniqueness. It is consequently often very difficult to obtain useful results in many practical applications. In recent years, significant progress has been made in solving such problems. Peter van den Berg and Aria Abubakar review and describe a class of methods that has been particularly successful for several types of real-world problems. The approach they use involves expressing the relationship between the measured, scattered fields and the unknown, desired contrast function of the object in terms of an integral equation. The source term in the equation is consists of the product of the field in the object and its contrast. The equation is solved iteratively for the contrast. At each step in the iteration, the difference between the measured data and the data resulting from the current solution for the contrast is minimized. There are several methods whereby constraints, based on a priori physical knowledge of the object, can be incorporated. The result is a solution approach that has proven to be quite robust in the presence of noise for a variety of real-world objects. The authors provide several synthetic examples to illustrate the method, and then give experimental examples to demonstrate its practical utility. These include examples from human microwave imaging, imaging of dielectric objects, and microwave imaging of objects buried in the ground. This paper was the Commission B tutorial at the Maastricht General Assembly.

Radio occultation is the process of looking at how radio waves are affected as an object moves in front of a radio source. Information can be obtained about the object from the effects on the waves. For example, information about the planetary atmosphere can be obtained as the edge of a planet moves across a radio source. In their paper, K. Noguchi, T. Imamura, K.-I. Oyama, and A. S. Nabatov describe the history and recent and planned future experiments in the space program of Japan using this technique. These experiments began in 1985, and currently planned work includes the exploration of the atmosphere of Venus in 2009. The paper provides a nice summary of both the experiments and the major discoveries made to date, with references for those who would like to obtain more information. This paper was originally presented at the Asia-Pacific Radio Science Conference (AP-RASC'01) in Japan, and was recommended by the conference's Program Committee.

Absorption by water vapor and liquid water in the atmosphere play a critical role in determining the propagation characteristics of microwaves, and this absorption is strongly dependent on frequency. Because of this, measurements at one or more carefully chosen microwave frequencies can permit significant information about atmospheric constituents and parameters to be determined. In particular, measurements at two or more frequencies can permit separating the effects due to water vapor and liquid water. While there have been studies of the optimum frequencies to use for such measurements for a variety of conditions and locations around the world, these may not be completely applicable for locations in which the variability of water vapor is very large, such as over Calcutta, India. In their paper, P. K. Karmakar, M. Maiti, S. Chattopadhyay, and M. Rahaman provide the results of a number of measurements directed toward determining the optimum frequencies to use for such remote sensing over Calcutta. Their results show that indeed the optimum frequencies do depend on the amount of water vapor present, and thus vary with the season. Spectra of the absorption over Calcutta are provided.

In his column on "Radio-Frequency Radiation Safety and Health," Jim Lin discusses a fascinating effect: the direct hearing of microwaves. Such auditory perceptions are not induced via airborne or bone-conducted energy, but are rather the result of the direct interaction of electromagnetic waves with the tissues of the head. It's something you should be aware of, and I think you'll find it fascinating.

Because this is the December issue of the *Bulletin*, it contains the annual directory of those involved in the Board, Council, Commissions, and the various committees of URSI, and those who represent URSI to other bodies. It also contains reports on URSI-sponsored and URSI-related meetings that have recently been held, and calls for papers for other, upcoming conferences. The annual International Geophysical Calendar for 2003 is also included. You should be keeping all of the issues of the *Bulletin*, of course, but this issue is one you'll want to keep available for ready reference.

The announcement of the topic for the 2004 International Electromagnetics Prize appears in this issue. The solutions are due by January 15, 2004.

Progress

About a year and one-half ago, a goal was set to substantially increase the technical content of the *Bulletin*. Thanks to all of those who have helped by contributing papers, and to all who have helped in identifying papers to be invited and in responding to those invitations, some significant progress has been made in achieving this goal. We currently have an average of about four papers scheduled for each issue through the end of 2003. Of course, not all of those have been received yet – and no Editor counts a paper until it is "in hand," ready to be published – but I'm optimistic! However, this by no means implies that we're "full," nor that additional papers will experience any delay in getting published. If you have material that is of interest across more than one URSI Commission, please consider submitting it to the *Bulletin*. We will *always* welcome good contributions.

Starting with the December, 2003, issue of the *Bulletin*, we will begin publishing what we are going to call the "Reviews of Radio Science." These are the peer-reviewed review papers on the topics identified by the Commissions as the most important within their field for the current triennia, authored by those invited by the Commissions as most appropriate to write the Reviews. In past triennia, these Reviews have been collected and published as a single book, distributed at the General Assembly. By action of the Council in Maastricht, beginning with this triennium, the Reviews will appear in the *Radio Science Bulletin*, spread over a three-year period. The process of getting the Reviews authored and reviewed involves a substantial amount of work: this is the responsibility of the Associate Editors for each Commission. Their names appear on the masthead of the *Bulletin*, and we owe them our thanks for taking on this very important responsibility. Coordinating their efforts and bringing the results together also involves a lot of work. I am very pleased to announce that Phil Wilkinson has agreed to take on this responsibility as Senior Associate Editor for the Reviews of Radio Science for the *Bulletin*. I appreciate his willingness to take on this very important job.

Happy New Year

A new year will arrive shortly after you get this issue. There are various opportunities at the end of the year for many of us to express our thanks for all we have received, and to look forward toward the year to come. I'm thankful for the honor and just plain fun of being able to edit this *Bulletin*. I'm especially thankful for the wonderful people I get to work with in doing so: Paul Lagasse, Inge Lievens, Inge Heleu, John Volakis, Phil Wilkinson, and our Associate Editors. They do an outstanding job, are wonderfully tolerant, and are truly professional scientific journalists. Thank you!

I hope that the new year will bring you health, peace, lots of interesting radio science to work on, and the opportunity for you to share it with our URSI community.

***Front cover**: Continued from page 2*

Figure 4. The image on the left is a full view of a 1.5 T spin-echo T2-weighted axial image, centered at the level of the septum pellucidum. Multiple high-signal regions are seen, representing multiple sclerosis (MS) plaques in the periventricular region, and affecting the corpus callosum. The image to the right is an 8 T low-flip-angle axial gradient-echo image, demonstrating much greater detail of the corpus callosum plaques. The corpus is slightly expanded, and demonstrates high signal intensity in the regions of pathology. The tentorium, pineal gland, and the deep veins all demonstrate very low signal intensity. (more on pp. 5-12)

High-Field Human MRI: Clinical Applications and Safety Aspects

A. Kangarlu
D.W. Chakeres

1. Introduction

The static magnetic field of whole-body magnetic-resonance-imaging (MRI) scanners has been continuously increasing [1]. Three- and four-Tesla (T) MRI systems occupied 20-30 MRI research laboratories around the world during the last two decades of the past century [2-4]. The advantages in signal-to-noise ratio (SNR) associated with the high-field systems made them popular for ever-widening applications in biomedical research. Functional MRI and in-vivo metabolic magnetic-resonance spectroscopy (MRS) flourished, with applications in many pathological conditions [2]. During the time that high-field technology was evolving into a powerful tool for clinical and biomedical research, the paramount concern regarding their integration into clinical settings has been the possible health risks associated with exposure to strong magnetic fields [5, 6]. Over the years, however, this issue has been addressed to the point that the US Food and Drug Administration (FDA) has authorized the use of up to 4 T magnets for routine clinical applications. It is conceivable that the field will soon be expanded to 8 T.

2. Clinical Applications

A whole-body 8 T/80 cm magnet was installed in the Department of Radiology at The Ohio State University in December, 1997. This represented a doubling of the strength of the magnetic field to which human subjects were previously exposed. In addition to the safety concerns, there were a myriad of technological issues that needed to be addressed. The spin-physics implications of such a magnetic field – i.e., relaxation effects, radio-frequency (RF) issues, magnetic susceptibly, etc. – applied to human subjects comprised a short list of the challenging issues that constitute a fertile ground for research work for the foreseeable future [7, 8]. Since that time, results have been generated at this field strength, demonstrating that wide-bore high-field (HF) MRI technology is indeed feasible and appropriate for both human and animal studies (Figure 1).

The images acquired at 8 T were excellent, despite inherent B1 inhomogeneities [B1 is the RF magnetic field, as distinguished from B0, the static magnetic field]. In addition, we have obtained a preliminary – although not exact – understanding of both T2* and T1 values at such fields for human tissues [T1 is the spin-lattice, or longitudinal, relaxation time; T2* is the effective transverse (sometimes called the spin-spin) relaxation time]. Detailed relaxation-

Figure 1. A view of the 8 T/80 cm human MRI scanner. The magnet is located within an iron room, built from more than 200 tons of iron, to contain the fringe field. The table is equipped with a cantilever top that delivers the subjects within the bore of the magnet. This picture shows the head gradient coil, the small cylinder at the center of the magnet.

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[Editor's note: This invited paper is the Commission K Tutorial Lecture, presented at the XXVII General Assembly of URSI in Maastricht, The Netherlands, 17-24 August, 2002.]

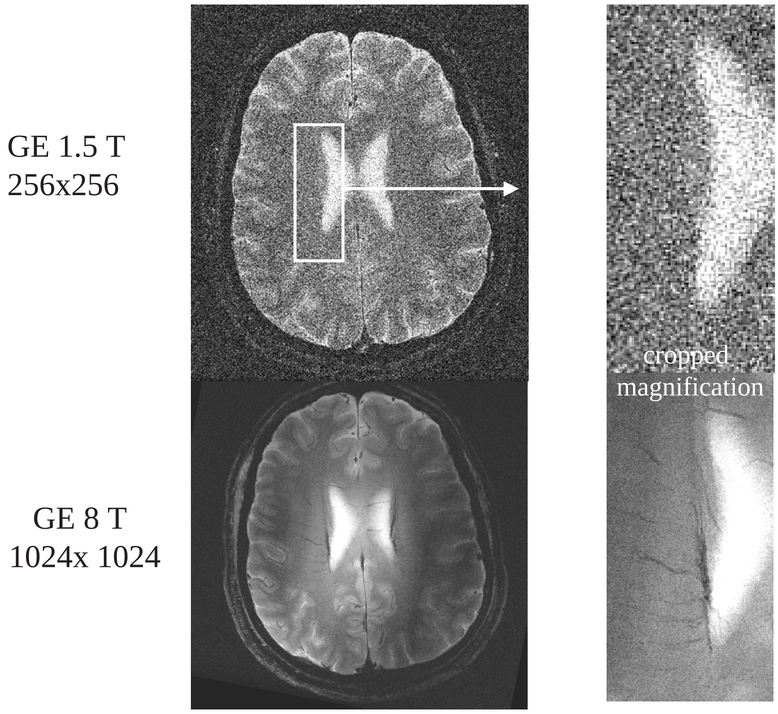


Figure 2. A comparison of 1.5 T and 8 T gradient-echo images. This figure compares 8 T and 1.5 T axial gradient-echo images, centered at the superior margin of the lateral ventricles of the same subject, obtained with comparable parameters in a 16 strut TEM RF coil. The 1.5 T images were acquired with a TR of 600, TE 40, flip 20 degrees, FOV 20 cm, 256 × 256 matrix. The 8 T images were acquired with similar parameters, but with TE of approximately 12, a matrix of 1024 × 1024, and a flip angle of approximately 20 degrees. The two sequences are designed to approximate each other. The full images are seen on the left; the cropped magnification images are seen on the right. The 1.5 T images are more homogeneous, but much noisier. The 8 T images demonstrate some lower signal in the left posterior parietal region. The cropped images demonstrate that the 8 T images demonstrate the subtle vessel detail of the medullary veins, while the 1.5 T images do not. We would like to thank Dr. Eric Bourekas for this image.

time measurements are very difficult to acquire, even in phantoms. We have also measured intrinsic SNR at this field strength, and have found it to be outstanding. Based on extensive measurements, these scanners are able to provide a SNR at the proton frequency which is nearly five to ten times that achievable on a conventional 1.5 T instrument for high-resolution imaging of humans. This signal-to-noise advantage can be translated either into decreased scan times, or into increased spatial resolution. When combined with the RF power requirements that can safely be achieved, the increased signal-to-noise ratio at 8 T becomes even more significant. In addition, along with the chemical-shift dispersion benefits at 8 T, this SNR will ensure that these scanners will have a significant impact on spectroscopic studies, once they are fully developed. Shimming at these high fields has required new strategies to overcome susceptibility variations, induced by the biological samples' inherent heterogeneity .

The high sensitivity to magnetic susceptibility differences at high field can also be used to advantage to produce very high-resolution gradient-echo (GRE) images of the cerebral venous system. This is due to the inherent T2* contrast related to deoxyhemoglobin on gradient-echo images, which is highly suitable for microneuroanatomy imaging. In Figure 2, a 1024 matrix gradient-echo image, acquired at 8 T from a human volunteer, is shown, in comparison with a 256-matrix slice at 1.5 T. The magnetic susceptibility advantages of the high field are best demonstrated here in terms of the in-vivo visualization of the microvasculature of the human brain.

Another early result of the 8 T human MRI was the finding of lower-than-expected RF power required to image the human head. Numerical simulations confirmed our initial observation that the RF power requirements at 8 T were lower than initially anticipated due to wave effects not seen at lower field strengths [9]. Because the wavelength of the RF energy and the head are approximately the same dimension, a detailed analysis of Maxwell's equations is essential for accurate simulations. These effects are not seen at lower field strengths. Another manifestation of this effect is the wide B1 variations encountered using standard RF volume head coils [7]. Accurately measuring flip angles is only possible in the presence of homogenous RF and, at high field, this is not easily achievable over a large sample. Thus, many of the current state-of-the-art sequences performed at lower fields can also be applied at fields up to 8 T, without a major risk to the patient of RF heating, or exceeding FDA guidelines. For instance, the fact that RF-power requirements were lower than expected at 8 T has enabled our group to acquire rapid-acquisition-by-relaxation-enhancement (RARE) images at this field strength [10]. This sequence is one of the most RF-intensive sequences in conventional MRI, and its safe implementation at 8 T is significant. This condition enabled us to justify extending the use of the high-field MRI to the study of pathology. A number of patients with multiple sclerosis (MS), stroke, brain tumor, etc., have been studied under Institutional Review Board (IRB) supervision with informed consent [11-13].

A distinct aspect of high-field MRI is the relaxation times, compared to lower fields. The T1 relaxation times are expected to increase and converge. Therefore, T1-weighted images do not have as great contrast as seen at lower fields. They are also more RF power intensive. The T2 relaxation times may decrease slightly, in part due to increased

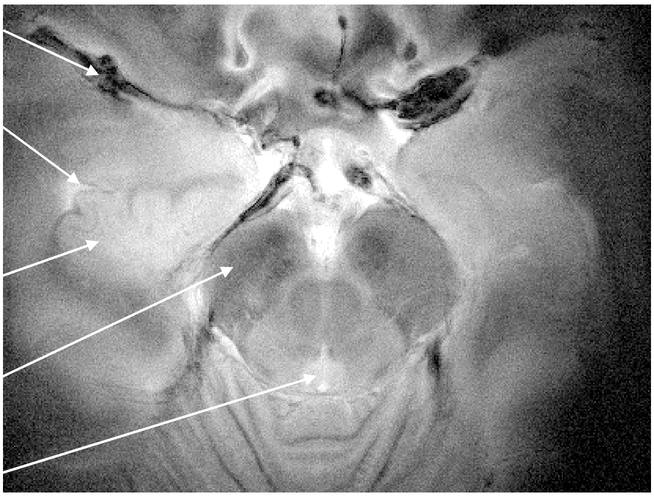


Figure 3. This is an axial 8 T gradient-echo image of a cadaver, centered through the anterior portions of the hippocampus. The middle cerebral arteries demonstrate very low signal, due to a high concentration of deoxyhemoglobin and very short T2 relaxation times. The temporal horn is seen to have high signal intensity, as do the other CSF spaces, such as the suprasella cistern and the cerebral aqueduct. The undulating configuration of the multiple layers of the hippocampus are well demonstrated. The lower-signal-intensity cerebral peduncle of the midbrain is labeled. We would like to thank Dr. Robert Dephilip for this image.*

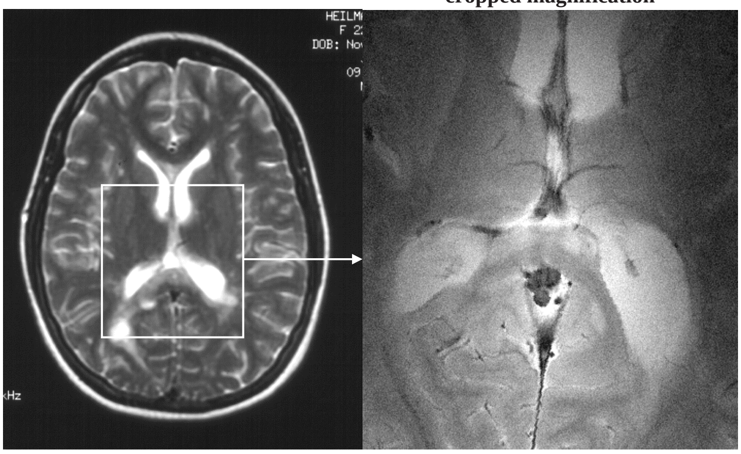


Figure 4. The image on the left is a full view of a 1.5 T spin-echo T2-weighted axial image, centered at the level of the septum pellucidum. Multiple high-signal regions are seen, representing multiple sclerosis (MS) plaques in the periventricular region, and affecting the corpus callosum. The image to the right is an 8 T low-flip-angle axial gradient-echo image, demonstrating much greater detail of the corpus callosum plaques. The corpus is slightly expanded, and demonstrates high signal intensity in the regions of pathology. The tentorium, pineal gland, and the deep veins all demonstrate very low signal intensity.

sensitivity to diffusion effects not seen at lower fields. These factors lead to a potential loss of SNR. The T2* relaxation times decrease with increasing static magnetic field. As a result, the gradient-echo images can take advantage of this unique contrast mechanism, and visualize structures smaller than the pixel size that are associated with local field inhomogeneities, such as paramagnetic deoxyhemoglobin or other contrast agents. In Figure 3, an axial 8 T gradient-echo image of a cadaver is shown, which is centered through the anterior portions of the hippocampus. The presence of deoxyhemoglobin has decreased T2*, and lowered the signal in the middle cerebral arteries. The cerebral spinal fluid (CSF) spaces of the temporal horn have high signal intensity. There is contrast between the gray- and white-matter structures. A clear visualization of the multiple layers of the hippocampus enables delineation of internal structures within it. This image is a good example of the unique contrast obtainable from human anatomy with high-field MRI.

In Figure 4, a comparison is made between images acquired at 1.5 T and 8 T from a multiple sclerosis (MS) patient. The 8 T images of the MS contain information about the relationship between the small veins and the MS plaques. This is potentially useful evidence to better characterize the etiology of white-matter lesions, and for classification of different subtypes of this disease. Studies are in progress to utilize the high resolution (<100 micron, in-plane) to study the MS plaques, and their mechanism of formation and their correlation with clinical disability. Such studies are valuable, in light of the absence of correlation at 1.5 T with progression of the disease, as measured by plaque numbers and surface area.

In another area of study, brain tumors of human subjects have been imaged at 8 T (see Figure 5) 8 T MRI has directly demonstrated the deformity of micro-vascular structures within tumors. High-grade gliomas are known to

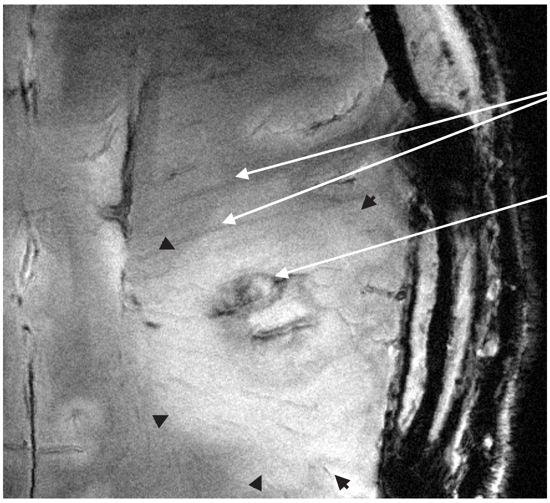


Figure 5. This axial 900 × 900 low-flip-angle gradient-echo image of the left posterior parietal region is centered on the infiltrating tumor. The tumor in general demonstrates increased signal intensity (black arrowheads), in contrast to the lower signal intensity white-matter tracts. The lesion is centered in the white matter, but extends from almost the lateral ventricle to the cerebral cortex. There is an irregular low-signal region in the center of the tumor, related to a previous biopsy and hemosiderin deposition. The deep medullary veins in the tumor are all enlarged and slightly tortuous. This is characteristic of high-grade tumors. They extend almost from the ventricle to the surface of the brain, similar to venous angiomas. We would like to thank Dr. Greg Christoforidis for this image.

be highly vascular, with dilated distorted vessels with an abnormally high vessel density. The veins demonstrate decreased signal intensity (black arrowheads), compared to the background brain gray- and white-matter structures. These images show a lesion in the white matter, extending from near the lateral ventricle to the cerebral cortex. The enlargement of the deep medullary veins, and a clear tortuous ecstatic pattern within the tumor, are seen. Our initial experience suggests that the greater the vessel deformities, the higher the tumor grade. In such applications, a quantitative study of the microvasculature could result in the direct in-vivo modeling of pathologic angiogenesis.

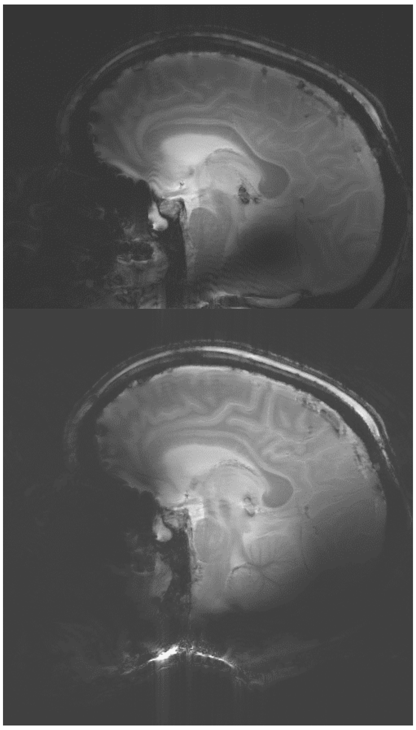
3. Safety Aspects

The human-head images, obtained at 8 T to date at our site, have been acquired with a volume transverse electromagnetic (TEM) RF coil. The high frequency of the proton precession, i.e., 340 MHz at 8 T, is associated with RF waves with 80 cm wavelength in air. Upon penetration into the human body, the RF wavelength, λ, reduces to about 10 cm, due to the dielectric value of the head tissues. The RF coils for this range of frequency are typically multi-modal. The TEM coils demonstrate modes with various degrees of inhomogeneous distribution across the head. The inhomogeneity of TEM modes have diagnostic, as well as safety, implications. The safety implications of high RF energy deposition, related to high-static-magnetic-field MRI systems, has been a safety concern during the entire history of MRI evolution. A thorough analysis of the biological effects of magnetic resonance (MR) has been published by our group [5, 6], dealing with a wide range of human safety issues. Of the three components of the MRI systems that are potentially capable of interaction with biological tissues, the static magnetic field and radio-frequency (RF) pulses are the most potent components, and the gradient field switching causes the most potentially benign safety effects. These interactions are basically in the form of molecular polarization and dielectric power deposition in the subject. Accordingly, all magnetic resonance systems have some RF power deposition and gradient switching in common. Aside from the variations of the interactions for different pulse sequences, the gradient effects are less dependent on the static magnetic field. In this regard, one should remember that the field-dependent effect on the relaxation mechanisms might require adjustments to the switching rate. These are rather straightforward mechanisms to investigate. In fact, with the constant demand for fast and ultra-fast imaging, extremely fast switching schemes have been contemplated even at lower fields, and have been analyzed and proven to be both feasible and safe.

In order to deal with the issue of RF inhomogeneity, we have designed and constructed TEM coils that depart from the traditional $\lambda/4$-length design. A $\lambda/8$ TEM 16-strut (11 cm) coil has been tested for its B1 inhomogeneity, compared to a more-standard 22 cm-length coil (see Figure 6). The improved B1 homogeneity is an area that is potentially capable of making a significant contribution toward the integration of high-field MRI into clinical settings. In addition, it has local SAR (Specific Absorption Rate) implications that represent a major source of concern for high-field MRI systems. B1 homogeneity improvement could be achieved through improved RF-coil design, pulse-sequence design, and transmit/detection schemes. This indicates that for a high-field magnetic-resonance scanner, the static magnetic field and the inhomogeneous RF remain the most distinct aspects of work aimed to assess the safety of a very-high-magnetic-field system.

Even though there are no known harmful effects as a result of the exposure of animals to a magnetic field of up to 9.4 T, and to humans of up to 4 T [14], a comprehensive safety study was necessary. These studies were conducted, and identified a few areas of concern. Specifically, recognizing the human cardiac sensitivity to induced electric potentials [15-19], we carried out a series of tests monitoring vital signs at high magnetic field. Due to the paramount

Long



Short

Figure 6. A set of gradient-echo images acquired from a cadaver head using two different TEM RF coils. The top image was acquired with a traditional 21 cm-long TEM coil. This image demonstrates a large area of low intensity, centered on the cerebellum and brainstem. These types of poor-performance regions are common, particularly in this area. The short (11 cm-long) TEM RF coil image is shown at the bottom. There is improved homogeneity in the central region of the brain, and the cerebellum is much better seen. This illustrates that the RF-coil design and the coil location can have a very significant effect on image quality. As with lower-field systems, multiple-coil systems will be needed for dedicate applications.

importance of the safety issue, a brief description of our studies are presented, as follows. In these experiments, certain measures, such as cardiac activity, were monitored before, during, and after each subject's exposure, for evaluation of the immediately detectable effects. In addition, in some studies – to address the cardiac effects, exclusively – no RF power or gradient switching for the human subjects were used. Each subject was monitored for core body temperature, blood pressure, pulse oxygenation, heart rate, electrocardiogram (ECG), and respiratory rate, before, during, and after the exposure to 8 T. In addition, in order to assess any short-term effects, a briefing of the subjects was conducted soon after the exposure, to allow them to express their experience.

All the subjects who participated in our study volunteered and gave informed consent. Institutional Review Board forms were filled out by all of these persons. During the past five years, a total of approximately 150 human subjects have been exposed or imaged in the 8 T MRI system. The study group consisted of Institutional Review Board protocols related to multiple sclerosis, brain tumors, safety, and stroke patients, including healthy volunteers. Not all of these had vital-sign measurements. In order to study the biological effects of the 8 T whole-body magnetic resonance imaging scanner exposure on the health of human subjects, approximately 100 volunteer studies were completed, focusing on the static-field effects. The measurement timing was not totally identical for all subjects, but measurements were made before entering the field both upright and supine, during exposure, and immediately after completion of the vital-sign monitoring in the supine and sitting-up positions. Subsequent to their screening for magnetic-field-sensitive conditions according to a questionnaire, their vital signs were measured. A designated physician handled all medical management issues. Frequent communications with the subjects while in the magnet were made, in order to inform them of different stages of the experiment, and to deal with possible anxiety due to the environment common for magnetic resonance studies, as well as to monitor for any adverse feeling.

We conducted a series of experiments designed to measure the heating effect of the exposure to high SAR levels, applied with a volume RF coil to a head phantom at 8 T, as well. In these experiments (in press) the purpose was to document any significant temperatures rises above the level recommended as safe by the FDA. Some RF-intensive sequences, such as rapid-acquisition by relaxation enhancement at 4 W/kg for 10 minutes, were applied, and the maximum temperature rises were recorded.

Most subjects had only a single exposure to the field of 8T, but a smaller number had multiple exposures, without reported problems. There was a broad range of vital-sign measurements for the same individual, even normally, out of the magnetic field. There was a rather wide range of normal vital-sign changes between upright and supine positions. In fact, these changes were larger than those measured related to the magnetic field. Typically, the pulse and blood pressure both fell in the supine position. We recorded no vital-sign changes that were symptomatic. We had one subject vomit, but otherwise the subject was stable, and no therapy was needed.

In terms of the subjects' experiences, common comments included that they experienced no effect, and were unaware of the magnetic field. The only physical discomfort was related to the vital measuring apprentice and the hard head coil. Other related comments that might have been associated with magnetic-field exposure included a sensation of transient dizziness while entering or leaving the magnet, a transient metallic taste, and coldness due to the cooled gradients. Only one subject described light flashes. A few subjects reported transient nystagmus, and this represented the only physical finding that could be directly seen. These experiences were not judged as severe or continuous. There is clearly a relationship between the rate at which the subject is advanced into the bore of the magnet and the incidence of dizziness. Slow insertion rates, of at least a few minutes, particularly at the internal bore of the magnet, significantly decreased the incidence of symptoms. The subjects did not express any changes in their mentation. There were no long-term effects reported by the subjects. All subjects returned to previous activities without interruption. Overall, there were no significant adverse events reported.

The electrocardiograms (ECGs), measured at fields of 0, 1.5, 3, 4.5, 6, and 8 T, are shown in Figure 7. There was increasing alteration of the ECG at higher field. The ECGs at 8 T were difficult to interpret, and we do not use cardiac monitoring during routine imaging studies. As expected, there was greater ST depression as the magnetic field increased. This is a known effect [15-19], and has been reported before. These changes are observed even at lower fields. The ECG changes reported due to the static magnetic field mostly include an enhanced T wave. The altered T wave is believed to be caused by a voltage induced by flowing blood within the static magnetic field [18, 19]. The conductivity of blood, and the fact that flow has the highest speed when the T wave is produced, creates a situation for the induction of the highest voltage through interaction with the magnetic field. This event coincides with ventricular contraction. The finite time interval between the R wave and the implication of its electrical signal and its interference with the contraction accounts for induction of the voltage during the time classically reserved for the T wave. These ECG changes do not appear to induce any cardiac function changes related to a significant alteration of blood pressure or pulse.

A number of subjects were evaluated with multiple measurements every 15 minutes in the magnet. They demonstrated some minor changes, but they were not

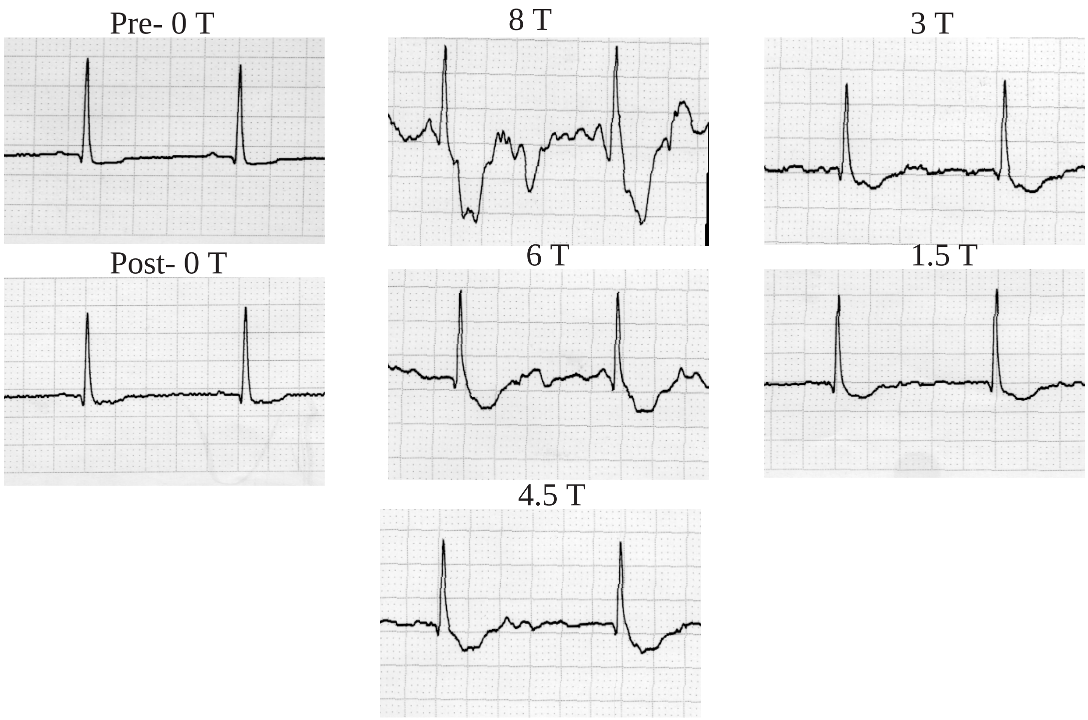


Figure 7. Serial electrocardiogram (ECG) measurements at various head field strengths. A series of two-lead ECGs were obtained on normal subjects at different positions in the magnet. The subjects were moved with their heads centered at various field strengths by moving the table position. The heart was not at the same field. Measurements were made in the supine position, pre- and post-magnetic exposure. Five measurements in decreasing magnetic fields (8, 6, 4.5, 3, 1.5 T), every five minutes, were made. This illustration demonstrates an example of all of the separate ECG measurements. There was no change from pre- to post-8 T exposure. Note that as the magnetic field increased, the ST depression increased. There was no clinically significant change in the cardiac heart rate, blood pressure, or finger pulse oxygenation levels related to the magnetic field.

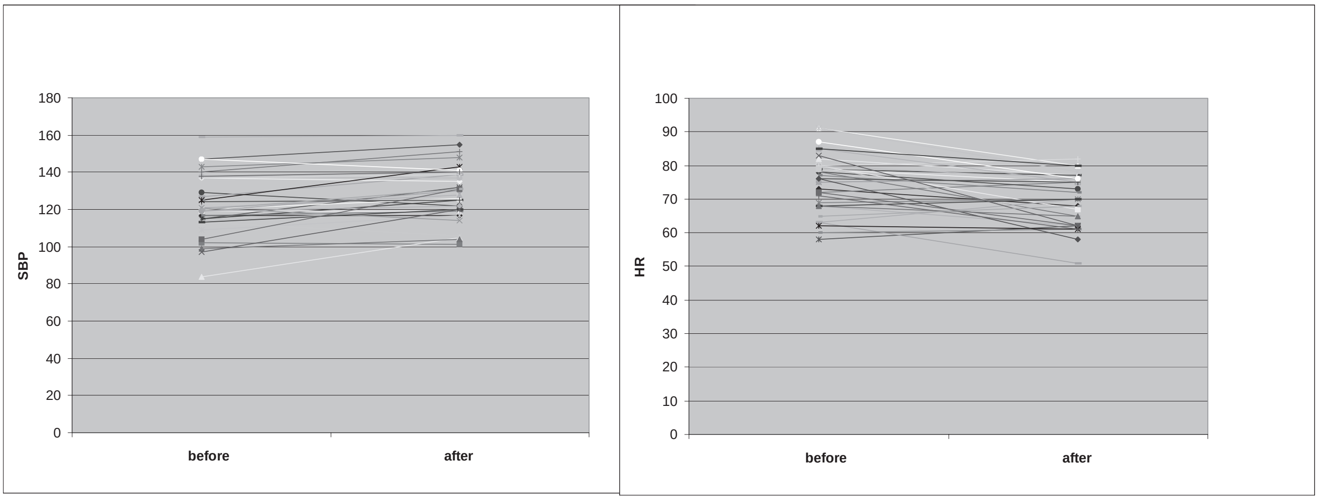


Figure 8. The systolic blood pressure (SBP) and heart rates of human volunteers, before and after exposure to a static magnetic field of 8 T for 1 hour. The graph on the left represents the subject's systolic blood pressure before and after exposure. There was no symptomatic or significant change, but there was a trend towards slightly higher pressures after exposure. The graph on the right shows the heart rates before and after exposure. There was a slight decrease after the exposure, but this is not unusual after lying flat for an interval.

significant. In addition, the blood pressures were measured before and immediately after exposure. Their measurements are plotted in Figure 8. This figure shows no symptomatic changes in the blood pressure of the subjects before and after the exposure. There was a slight increase in blood pressure on first exposure to the high magnetic field, but this change was in the range measured between the supine and upright positions, so it is not significant. There was a general trend of the pulse rates to be lower at the end of the procedure. This was anticipated, since the subject was at rest for a significant interval of time.

Interestingly, among the subjects who were monitored within the magnet, a greater change in the vital signs was observed as a result of a change in their position than as a result of their being supine in or out of the magnet. This was between sitting upright or laying supine before they were exposed and while they were out of the magnet.

In case of the RF heating effect at high field, our human-head model measurements demonstrated that the rapid-acquisition-by-relaxation enhancement sequence, with 4 W/kg irradiation, was shown to produce a maximum temperature increase of about less than one degree centigrade. We have never operated at these high RF power levels. Furthermore, low RF power pulses, which are routinely used in diagnostic human imaging, were demonstrated to produce essentially no temperature increases for the sensitivity of the measurement techniques to approximately 0.1° C. We did not detect any extreme local heating during these measurements. The RF heating was greater centrally within the phantom than at the periphery, which was predicted by numerical calculations.

4. Conclusion

We have demonstrated that high-field MRI is feasible for human imaging. Very-high-resolution images have been acquired from the human head, with the indication of the potential for applications in a number of different pathologies. In this regard, in addition to healthy subject studies, a number of multiple sclerosis, brain tumor, and stroke patients have been studied at this field. Images were acquired for the first time from the whole human head, with in-plane resolution of 100 microns. Direct microvasculature imaging has the potential to evaluate brain-vessel abnormalities from a new perspective. Such studies have the potential of shedding light on some diseases, such as Alzheimer's disease, Parkinson's disease, multiple sclerosis, stroke, and cancer. Safety studies, to date, have not documented any clearly hazardous effects of the measured vital-sign parameters, as they were compared before, during, and after the exposure. The results suggest that there are no clinically significant measurable effects as a result of exposure to the field of 0 to 8 T. Variation in blood pressure changes in the supine and upright positions was the most significant finding of these experiments. It is important to note that comments by some volunteers for high-field exposure in the past were related to the sensations they experienced during insertion and removal into the magnet. These experiences have many reasons, some of which depend on the method of insertion of the subject into the field. It is well known that a sudden, fast motion of the head inside the magnetic field will cause dizziness and a possible loss of balance. We have intentionally taken extra time to direct the volunteers in and out of the field very slowly. These results are reassuring, in so far as the observed effects of the exposure of the human subjects to a field of up to 8 T are concerned. They do not, however, exclude any possible long-term effects, or more subtle effects not reflected in vital-sign changes, but just as with animal studies, it may be very difficult to document long-term magnetic-field effects.

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Inverse Scattering and its Applications to Medical Imaging and Subsurface Sensing

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Abstract

This paper will review a number of algorithms for solving the nonlinear inverse-scattering problem, where the discrepancy between the measured data and the predicted data is minimized. These algorithms are all based on a source-type of integral representation of the scattered field, where the integral operator acts on a contrast source, which is the product of the interior field and the contrast of the scattering object. Special attention is paid to the development of the contrast-source-inversion method, where the contrast sources are updated iteratively, and where, in each iteration, an explicit "minimizer" is obtained for the contrast. We discuss the efficient implementation of extra constraints, such as the total variation of the contrast, leading to the concept of a multiplicative constraint. We present actual reconstructions from both synthetic and experimental scattered-field data, with applications to medical imaging and subsurface sensing.

1. Introduction

Suppose we have a known incident wave field as it is emitted from a source into a more-or-less penetrable obstacle or a set of obstacles, collectively called the scattering object. The incident wave field is scattered by this object. In forward-scattering modeling, one aims to develop the computational tools to calculate the scattered wave field at points of interest, for a known incident field and a known scattering object. The underlying scattering model is linear.

In inverse-scattering modeling, one aims to determine the shape, location, and constitutive parameters of the object from measurements of the scattered wave field, when a number of electromagnetic waves are generated such that they successively illuminate the domain of interest. Since the wave fields depend on the material parameters, the inverse-scattering problem is essentially nonlinear.

For simple forward-scattering models, a forward solver can generate a database containing a full collection of scattered-field data for a number of possible realizations of the scattering object, and one can then select a particular realization with the "best" fit to the actually measured data. But, in practice, the execution of such an enumerate inversion method is often impossible, due to the large number of discrete unknown variables. Improvements of these Monte Carlo methods [1] are obtained when certain probability is taking into account, e.g., as in genetic algorithms [2]. The advantages of these inversion schemes are the simplicity, and the feature that the algorithm will not trap into a local minimum. However, the major disadvantage is the large number of forward solutions to be generated – and, presently, for a realistic full three-dimensional scattering problem (including multiple scattering) – the generation of a full class of forward solutions is not feasible.

We therefore opt for an iterative approach, where the wave fields and the material parameters are updated iteratively by a consistent minimization of the misfit between the actual data and the modeled data. Since the updates of the fields and the contrast are determined from the misfit, precaution has to be taken to overcome the ill-posed nature of the inversion problem, and to avoid the local minima of the nonlinear problem.

In this paper, we utilize the domain source-type integral representation of the scattered field to minimize the discrepancy between the measured data and predicted data as a function of the material contrast. This contrast is defined as the difference between the constitutive parameters of the scattering object under consideration and those of a known background medium. By using the source-type integral equation, we focus on the contrasting domain.

Starting with the Born approximation, we review distorted-Born, Newton-Kantorovich, and gradient types of algorithms in a nonlinear framework, for reconstruction of a complex contrast (including permittivity and conductivity) from scattered-field data. In these methods, the fields and the contrast are considered to be fundamental unknowns. Since the inverse-scattering problem is nonlinear,

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[Editor's note: This invited paper is the Commission B Tutorial Lecture, presented at the XXVII General Assembly of URSI in Maastricht, The Netherlands, 17-24 August, 2002.]

the methods are iterative in nature. Each iteration requires the solution of a forward problem where, for given contrast, the pertaining field solution is computed. This complication is avoided in the modified gradient method by optimizing a cost functional, such that the unknown fields and contrast are updated iteratively. The cost functional consists of the superposition of the mismatch between the measured field data and predicted data, and the error in satisfying consistency in the interior of the object. In these relations, an integral operator acts on the contrast source, which is the product of the unknown field and the unknown contrast. Therefore, a more efficient and versatile algorithm is developed, in which the contrast sources and the contrast are considered as fundamental unknowns. In this so-called contrast-source-inversion method, the minimization of the two-term cost functional is carried out in two alternate steps: (1) the contrast sources are updated via a conjugate-gradient direction of the two terms; and (2) the contrast is found by direct minimization of the second term, which is equivalent to find the least-squares fit of the constitutive relations between the contrast sources and the fields. In view of the simplicity of the relations for the contrast, we discuss the efficient implementation of extra constraints, such as the total variation of the contrast. A non-conventional multiplicative constraint is employed. It appears to be very effective without major a priori information about the shape and constitution of the object configuration. Employing the contrast-source-inversion method with multiplicative constraint, we discuss the actual reconstruction of realistic configurations from both synthetic and experimental scattered-field data; in particular, we discuss examples from medical imaging and subsurface sensing.

2. Domain Integral Equations

We consider a scattering object of arbitrary bounded cross section. We assume that this unknown scatterer is contained in the test domain, *D* (Figure 1). Spatial points are denoted as $\mathbf{p} = (x_p, y_p, z_p)$ and $\mathbf{q} = (x_q, y_q, z_q)$. This constitutes a priori information about the approximate location of the scattering object. The domain, *D*, may be chosen quite large to insure inclusion of the unknown scattering object, but this incurs a computational price. We assume that the fields vary sinusoidally in time, with frequency ω. We also assume that we know the Green's function as the fundamental solution (a line source in two dimensions, and a point source in three dimensions) in the embedding medium.

We further assume that the object is successively irradiated by a number of known incident fields, $u_j^{inc}(\mathbf{p})$, $j = 1, \ldots, J$, originating from different source positions. For each incident field, the total field will be denoted by $u_j(\mathbf{p})$ in *D*, and by

$$u_j(\mathbf{p}) = u_j^{inc}(\mathbf{p}) + u_j^{sct}(\mathbf{p}) \qquad (1)$$

exterior to *D*. In the inverse-scattering problem, the scattered field, u_j^{sct}, will be measured on some surface, *S*, outside the test domain, *D* (see Figure 1).

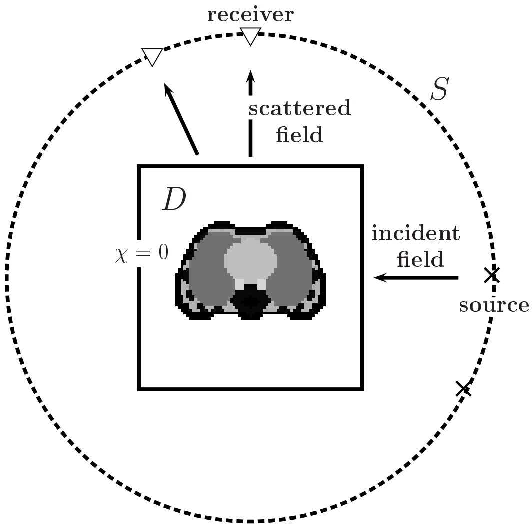

Figure 1. The scattering configuration enclosed in a test domain, D.

Nowadays, it is well known [3] that the total field and the scattered field satisfy the following domain integral representations, written in operator form as

$$u_j(\mathbf{p}) = u_j^{inc}(\mathbf{p}) + G_D \chi u_j, \quad \mathbf{p} \in D, \qquad (2)$$

$$u_j^{sct}(\mathbf{p}) = G_S \chi u_j, \quad \mathbf{p} \in S, \qquad (3)$$

where $\chi(\mathbf{q})$ denotes the contrast of the object with respect to its embedding medium. Clearly, $\chi(\mathbf{q}) = 0$ at those points in *D* exterior to the actual scattering object (see Figure 1). The operators are source-type integral representations [4], and represent the field due to a superposition of contrast sources, $w_j = \chi u_j$. They are given by

$$G_{S,D} w_j = \int_{\mathbf{q} \in D} G(\mathbf{p}, \mathbf{q}) w_j(\mathbf{q}) dv, \quad \mathbf{p} \in \{S, D\}, \qquad (4)$$

where $G(\mathbf{p}, \mathbf{q})$ is the fundamental point-source solution in the embedding medium, often denoted the Green's (tensor) function. We assume that this Green's function is known. The subscripts *S* and *D* are appended to the integral operator *G* to clarify where in space the field point, $\mathbf{p}$, is located.

Let the scattered field measured on *S* be denoted as f_j. Then, the representation in Equation (3) is written symbolically as the *data equation*,

$$f_j = G_S \chi u_j, \quad \mathbf{p} \in S, \qquad (5)$$

while the integral equation, Equation (2), is written symbolically as the *object equation*,

$$u_j^{inc} = u_j - G_D \chi u_j, \quad \mathbf{p} \in D. \tag{6}$$

Let us further denote the norm and inner product in $L^2(S)$ and $L^2(D)$ by appending a subscript S or D as appropriate, viz., $\| \|_S$ and $\| \|_D$.

3. Inverse-Scattering Problem

If the scattered field is measured on S to be $f_j(\mathbf{p})$ – which includes measurement error, noise, and any other signal contamination – then Equation (5) will not, in general, be satisfied if f_j replaces u_j^{sct}. In fact, we use this data equation to define the discrepancy between the measured data and the predicted scattered field corresponding to χ and u_j in D. The inverse-scattering problem consists of determining $\chi(\mathbf{p})$ from a knowledge of the incident fields, $u_j^{inc}(\mathbf{p})$, on D, and the scattered fields, $f_j(\mathbf{p})$, on S. Since the inverse problem is nonlinear, we recast it as an optimization problem of finding χ to minimize the error in the data equation, Equation (5), subject to the constraint that the object equation, Equation (6), is satisfied in some sense. The existence of a "minimizer" can be guaranteed by a suitable choice of the class of admissible values of χ. However, whether this minimizer is related to a local or global minimum remains an ongoing concern.

An obvious solution of the inverse problem involves a substitution of the formal solution of the object question, Equation (6),

$$u_j = L^{-1} u_j^{\text{inc}}, \quad L = I - G_D \chi, \tag{7}$$

into the data equation, Equation (5). Then the data error becomes

$$\rho_j = f_j - G_S \chi L^{-1} u_j^{inc}, \tag{8}$$

and the inverse problem is posed as determining χ from a minimization of the cost functional

$$F(\chi) = \frac{\sum_j \| \rho_j(\chi) \|_S^2}{\sum_j \| f_j \|_S^2}. \tag{9}$$

Other normalizations of the cost functional are possible. This is a classic example of an ill-posed problem, and is treated by adding Tikhonov regularizers to the cost functional.

3.1 Born Type of Methods

When the scatterer is small and/or the contrast is small (so-called weak scatterers), then the well-known Born approximation consists of taking the field to be the incident field, viz., $u_j \approx u_j^{inc}$ in D. This, in fact, is the first term in a Neumann-series solution of the object equation: that is, approximating

$$L^{-1} = (I - G_D \chi)^{-1} \approx I. \tag{10}$$

The effectiveness of this approach is severely limited by the approximation of the field in D.

A surprising improvement over the Born approximation is achieved in the extended Born approximation [5], by approximating

$$L^{-1} = (I - G_D \chi)^{-1} \approx \frac{I}{1 - G_D \chi}. \tag{11}$$

This appears, at first glance, to be a confusion between the symbol for operator inverse and reciprocal. However, it results from an approximation of the field u_j in the integral term in the object equation, Equation (5), by the first term in a Taylor expansion about the field point. This leads to an approximate object equation,

$$u_j^{inc} = u_j - u_j G_D \chi, \quad \mathbf{p} \in D, \tag{12}$$

the solution of which is equivalent to the curious form of the approximate inverse given above. This method is more effective than the Born approximation in reconstructing weak scatterers.

Iterative improvement of the Born approximation is achieved with the following approach [6]. A sequence of functions, $\{\chi_n\}$, is determined by minimizing, for each n, the cost functional

$$F_n(\chi_n) = \frac{\sum_j \| \rho_{j,n} \|_S^2}{\sum_j \| f_j \|_S^2}, \quad n = 1, 2, \ldots, \tag{13}$$

with

$$\rho_{j,n} = f_j - G_S \chi_n u_{j,n} \tag{14}$$

and

$$u_{j,n} = L_n^{-1} u_j^{inc}, \quad L_n = I - G_D \chi_{n-1}. \tag{15}$$

One can start with an initial guess of $\chi_0 = 0$, but other choices may be used advantageously. This is true of any of the iterative methods described here. Because of the lack of uniqueness – especially in the finite-dimensional versions of the optimization algorithms – one expects the occurrence of local minima in the cost functional. Improving the initial guess by incorporating as much a priori information as possible is often looked on as a way of avoiding being trapped in such local minima. However, this does not diminish the importance of building a priori information into the cost functional itself whenever possible [7]. As in the Born approximation, the optimization problem is solved by adding regularizers to the cost functional. It should be pointed out that in this approach, calculation of the quantity $L_n^{-1} u_j^{inc}$ is required, and this means that the object equation, Equation (6), must be solved at each iteration. This is a feature of a number of iterative methods, and this can be computationally challenging without a very efficient forward solver. Even with a good solver, the work at each step will be increased, and this will be more noticeable if a large number of iterations is used.

The cost functional to be minimized in the iterative Born method may be obtained by neglecting all but the zero-order term in an expansion of the inverse, $L^{-1} = \left(I - G_D \chi\right)^{-1}$, in powers of $\delta_\chi = \chi - \chi_{n-1}$. If terms of order $O\left(\delta_\chi\right)$ are retained, we obtain the Newton-Kantorovich algorithm [8, 9], where we arrive at a new update as being $\chi_n - \chi_{n-1} + \delta_\chi$, where δ_χ is obtained by minimization of

$$F_n\left(\delta_\chi\right) = \frac{\sum_j \left\| \rho_{j,n} - G_S \left(I - \chi_{n-1} G_D\right)^{-1} \delta \chi u_{j,n} \right\|_S^2}{\sum_j \left\| f_j \right\|_S^2}, \quad (16)$$

where $u_{j,n}$ is again determined as the solution of the forward problem, see Equation (15). As before, the optimization problem is solved by adding regularizers to the cost functional.

Another inversion scheme is the distorted Born algorithm [10]. Here, in each iteration, the Green's function in the data equation is updated by replacing the embedding by the approximate medium reconstructed in the previous iteration. If χ_n is known, a distorted Green's function is defined with respect to a distorted embedding. This method is completely equivalent to the Newton-Kantorovich method [11].

3.2 System Formulation

All of the methods so far involved utilizing various approximations to the formal solution of the object equation, Equation (7), in the data error, Equation (8). The optimization problem then involved finding updates to the contrast by minimizing the norm of the data error. This is attractive conceptually, since it apparently reduces the size of the optimization problem. However, this advantage is offset by the fact that the field is either held fixed (the Born approximation), which severely limits the range of contrasts which may be reconstructed, or the field is updated at each iteration by solving a forward problem, Equation (7), with the most recent update of the contrast. The fact that large contrasts increase the nonlinear dependence of the fields and the data on the incident fields constitutes a serious limitation on all of the inversion algorithms described. An alternative approach involves the simultaneous solution of the system of equations

$$u_j - G_D \chi u_j = u_j^{inc},$$

$$G_S \chi u_j = f_j, \; j = 1, \ldots, J, \quad (17)$$

for the $J+1$ unknown functions u_j and χ in *D*. One attack to solve this problem [12] is to form one unknown vector, $\mathbf{x} = \left(u_1, u_2, \ldots, u_J, \chi\right)$, the dimension of which may be extremely large when the functions u_j and χ are discretized. Then the system of nonlinear equations, Equation (17), may be solved by a standard nonlinear optimization method, using a conjugate-gradient algorithm with the updates

$$\mathbf{x}_n = \mathbf{x}_{n-1} + \alpha_n^x \mathbf{v}_n, \quad (18)$$

where $\mathbf{v}_n$ is a conjugate-gradient update vector. α_n^x is a weight that is determined by a minimization of

$$F_n\left(u_{j,n}, \chi_n\right) = \frac{\sum_j \left\| \rho_{j,n} \right\|_S^2}{\sum_j \left\| f_j \right\|_S^2} + \frac{\sum_j \left\| r_{j,n} \right\|_D^2}{\sum_j \left\| u_j^{inc} \right\|_D^2}, \quad (19)$$

where

$$\rho_{j,n} = f_j - G_S \chi_n u_{j,n},$$

$$r_{j,n} = u_j^{inc} - u_{j,n} + G_D \chi_n u_{j,n}. \quad (20)$$

The weights in the cost functional, Equation (19), are chosen to balance the two error functionals that make up F_n, in the sense that they are both equal to one if $u_j = \chi = 0$. This choice also ensures that the functional is insensitive to changes in the overall magnitude of the incident field and the data.

This approach has the advantage of avoiding the necessity of solving a forward problem to update the fields, u_j, at each iteration. Further, the nonlinearity is only present as a bilinear form, χu_j. In fact, when we perturb the solution vector $\mathbf{x} = \left(u_1, u_2, \ldots, u_J, \chi\right)$ linearly, the cost functional, Equation (19), is a fourth-degree polynomial of the real perturbation parameter. This enables us to derive conditions for the existence of one global minimum and the absence of local minima [13]. The present approach has the disadvantage that the gradients are somewhat complicated and the space of unknowns involved is very large. In addition, the gradient contains two completely different physical quantities with different dimensions. The standard conjugate-gradient method needs a large number of iterations. One way to avoid these disadvantages is to treat the fields and the contrast separately, as described in the next subsection.

3.3 Modified Gradient Method

The basic idea of the modified gradient method [14, 15] for solving the inverse problem is the iterative construction of sequences, $\{u_{j,n}\}$ and $\{\chi_n\}$, which converge to minimizers of the functional in Equation (19). Specifically, we define the updates

$$u_{j,n} = u_{j,n-1} + \alpha_n^u v_{j,n},$$
$$\chi_n = \chi_{n-1} + \alpha_n^\chi d_n \cdot \tag{21}$$

For each $n = 1, 2, \ldots,$ the functions $v_{j,n}$ and d_n are update directions for the functions $u_{j,n}$ and χ_n, respectively, while the constants α_n^u and α_n^χ are weights to be determined by a minimization of the cost functional of Equation (19). As the update direction for the field, we take the conjugate-gradient direction of F_{n-1} with respect to changes in the field u_j (assuming fixed contrast), while as the update direction for the contrast, we take the conjugate-gradient direction of F_{n-1} with respect to changes in the contrast χ (assuming fixed fields).

The modified gradient method has been successful in the reconstruction of complex objects, although the physical requirement of positive imaginary part of the medium parameters increases the stability of the method. With the inclusion of the non-negativity of the imaginary part of the contrast, the modified gradient method may also be used for reconstructing the location and shape of the boundary of an impenetrable object without making the a priori assumption of impenetrability [16]. This observation is also confirmed by the results of a blind reconstruction from experimental data [17]. It is further remarked that for the special case where the object is homogeneous, and where its contrast is an a priori known constant, but where the geometry is unknown, a binary constrained inversion of the modified gradient method algorithm has been developed successfully [18].

4. Contrast Source Inversion

In the modified gradient method, the fields and the material contrast are updated simultaneously. However, one can also invert for the contrast sources and the contrast. We observe that the data equation contains both the unknown field and the unknown contrast in the form of a product,

$$w_j(\mathbf{p}) = \chi(\mathbf{p}) u_j(\mathbf{p}), \mathbf{p} \in D, \tag{22}$$

which can be considered to be an equivalent source that produces the measured scattered field. This equivalent source is called a contrast source, and is a measure for the contrasting scatterer in *D*. The data equation becomes

$$f_j = G_S w_j, \ \mathbf{p} \in S, \tag{23}$$

while the object equation for the field is rewritten as

$$u_j = u_j^{inc} + G_D w_j, \ \mathbf{p} \in D \cdot \tag{24}$$

Substituting this equation into Equation (22), we obtain an object equation for the contrast source rather than for the field, viz.,

$$\chi u_j^{inc} = w_j - G_D w_j, \ \mathbf{p} \in D \cdot \tag{25}$$

The data equation, Equation (23), is called a source-type integral solution. Although this equation is linear in the contrast source, it is a classic ill-posed equation and, for a time, there was considerable attention paid to the question of uniqueness [19]. It was shown that there exist non-trivial solutions of the homogeneous form of Equation (23), although it was argued by some that uniqueness could be restored from physical considerations. Moreover, it has also been shown that the minimum-norm solution of Equation (23) – the solution produced, for example, by the conjugate-gradient method – is not the appropriate physical solution. Nonetheless, this source-type equation has served as an essential ingredient in many inversion procedures [20].

The contrast-source-inversion method [21] recasts the inverse problem as an optimization problem, in which we seek not only the contrast sources but also the contrast itself. This is done so as to minimize a cost functional consisting of two terms, the error norms in the data equation and in the object equation, rewritten in terms of the contrast course and the contrast, viz.,

$$F_n(w_{j,n}, \chi_n) = \frac{\sum_j \|\rho_{j,n}\|_S^2}{\sum_j \|f_j\|_S^2} + \frac{\sum_j \|r_{j,n}\|_D^2}{\sum_j \|\chi_{n-1} u_j^{inc}\|_D^2}, \tag{26}$$

where

$$\rho_{j,n} = f_j = G_S w_{j,n},$$
$$r_{j,n} = \chi_n u_j^{inc} - w_{j,n} + \chi_n G_D w_{j,n} \cdot \tag{27}$$

The inversion algorithm constructs sequences $\{w_{j,n}\}$ and $\{\chi_n\}$ that iteratively reduce the value of the cost functional. Although this updating of the fields and contrast can be carried out simultaneously, an alternating updating scheme simplifies the algorithm significantly. In addition, it is noted that, for given contrast, the second term in the cost functional of Equation (26) makes the problem of determining the contrast sources well posed.

4.1 Updating of the Contrast Sources

Suppose $w_{j,n-1}$ and χ_{n-1} are known. We update w_j by

$$w_{j,n} = w_{j,n-1} + \alpha_n^w v_{j,n}, \tag{28}$$

where $v_{j,n}$ is the conjugate-gradient direction of F_{n-1} of Equation (26) with respect to changes in the contrast source, and the weight α_n^w is determined by minimization of the cost functional of Equation (26). Once the contrast course $w_{j,n}$ is found, the field $u_{j,n}$ is determined directly from Equation (24).

4.2 Updating of the Contrast

We note that the contrast is only present in the second term of the cost functional, Equation (26), which we write as

$$F_D(\chi) = \frac{\sum_j \left\| \chi u_{j,n} - w_{j,n} \right\|_D^2}{\sum_j \left\| \chi_{n-1} u_j^{inc} \right\|_D^2}, \qquad (29)$$

where $u_{j,n} = u_j^{inc} + G_D w_{j,n}$. In view of the simplicity of the cost functional, it can be minimized analytically by taking the contrast to be

$$\chi_n^{analyt} = \frac{\sum_j w_{j,n} \bar{u}_{j,n}}{\sum_j \left| u_{j,n} \right|^2}. \qquad (30)$$

In view of this analytical minimization, it is anticipated that the ill-posedness of the inverse problem has been avoided here, while in all previous methods, an operator acts on the contrast and a numerical inversion of the ill-posed operator may lead to numerical instabilities.

4.3 A Synthetic Example

We illustrate the effectiveness of the contrast-source-inversion method, compared to the modified gradient method, with a numerical example of the scattering by a two-dimensional object. The object consists of concentric square cylinders: an inner cylinder, λ by λ, with contrast $\chi = 0.6 + 0.2i$, surrounded by an outer cylinder, 2λ by 2λ, with contrast $\chi = 0.3 + 0.4i$, as shown in Figure 2a. The measurement (surface) domain, *S*, was chosen to be a circle of radius 3λ, containing the test domain *D*. *D* was a square 3λ by 3λ, where λ is the wavelength in the

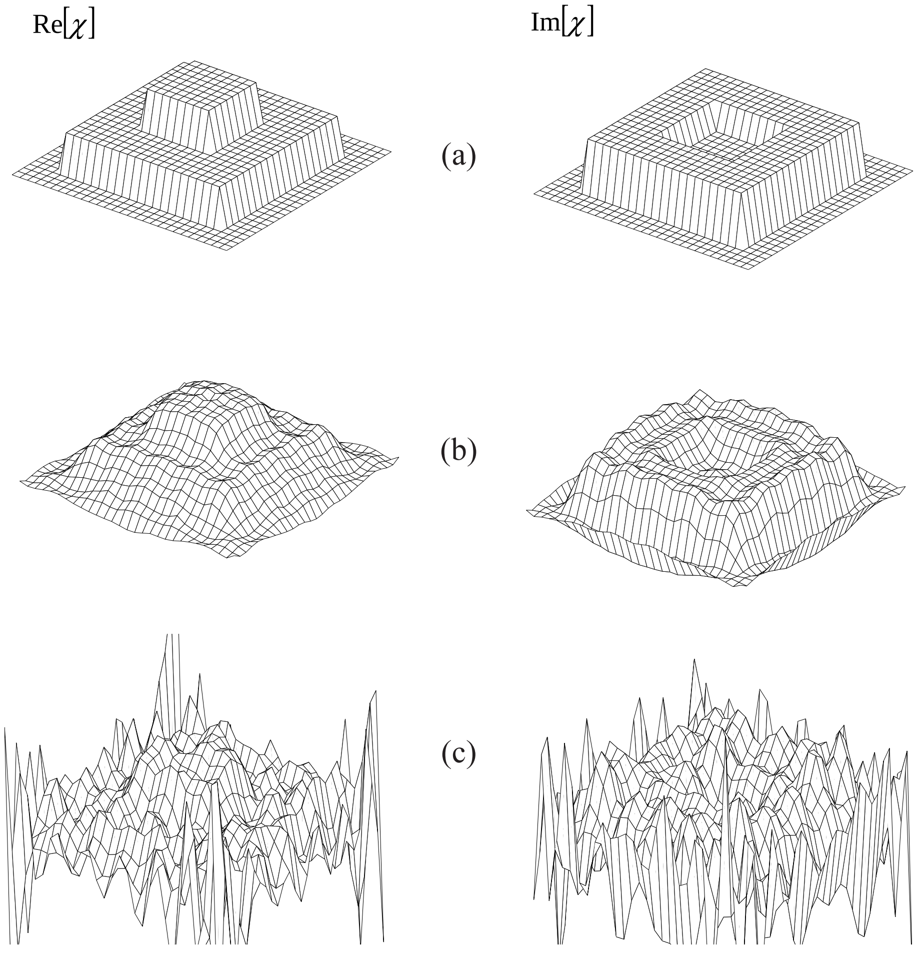

Figure 2. The original profile of the concentric squares (a), and the profiles reconstructed with the modified gradient method after 128 iterations: (b) without noise, and (c) with 10% noise.

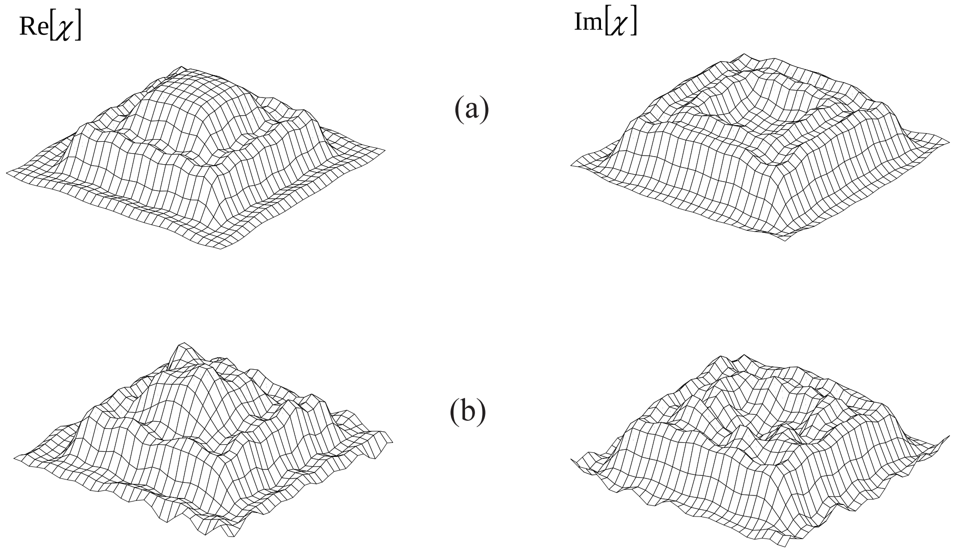

Figure 3. The profile of the concentric squares reconstructed with the contrast-source-inversion method after 128 iterations: (a) without noise, and (b) with 10% noise.

homogeneous background medium. Thirty stations were located uniformly on the circle *S*, with each station serving successively as a line source and all stations acting as receivers. In the numerical examples, the test domain was discretized into 29 x 29 sub-squares. Synthetic "measured" data were found by numerical solution of the forward problem. The reconstructions after 128 iterations are shown in Figure 2b for the modified gradient method, and in Figure 3a for the contrast-source-inversion method. The reconstruction results using both methods were comparable. However, when we altered the synthetic data by adding white noise with a maximum amplitude of 10% of the maximum of the uncorrupted data, the modified gradient became unstable (see Figure 2c), while the contrast-source-inversion methods still yielded a good reconstruction result (see Figure 3b).

In view of this robustness of the contrast-source-inversion method, a strong preference is given to this method. A further advantage is that the a priori information with respect to the contrast is easily included in the updating step of the contrast.

5. Extra Regularization

When the number of data is limited and a significant noise level is present in the data, one way to operate is to limit the number of unknown parameters in the contrast, or, in other words, to limit the spatial variation of the contrast. On the other hand, the question becomes how to restore the band limitation of the images we have obtained with the contrast-source-inversion method. In image processing, there are a number of methods to enhance an image by minimization of the total variation. Our next strategy is to combine one and another by minimization of the total variation, this being some norm of the gradient $\nabla\chi$, during the whole inversion process. Use is made of a cost functional with a norm, say $F_n^R(\nabla\chi)$. The standard way is to include such a norm in the cost functional by introducing an extra penalty function, viz.,

$$\mathcal{F}_n\left(w_{j,n},\chi_n\right)=F_n\left(w_{j,n},\chi_n\right)+\gamma^2 F_n^R\left(\nabla\chi_n\right). \quad (31)$$

As known in the literature, the addition of the regularization term, F_n^R, to the cost functional has a very positive effect on the quality of the reconstruction. The total variation as an L^1 norm has been used by adding it as a penalty function to the modified gradient algorithm [22] and the contrast-source-inversion method [23], resulting in a substantial improvement of the performance of the reconstruction methods, both for "blocky" and smooth contrast configurations. The drawback is the presence of the positive weighting parameter γ^2 in the cost functional, which, with the present knowledge, can only be determined through considerable numerical experimentation and a priori information about the desired reconstruction. Further, numerical experiments have shown that the results improve when we let the parameter γ^2 decrease with an increasing number of iterations. In fact, a good choice seems to be to take this parameter to be proportional to the value of the cost functional, F_{n-1}, of the previous iteration. This numerical experimentation has led us to the idea of the multiplicative regularization technique [23], viz.,

$$\mathcal{F}_n\left(w_{j,n},\chi_n\right)=F_n\left(w_{j,n},\chi_n\right)\times F_n^R\left(\nabla\chi_n\right). \quad (32)$$

Minimization of this functional with respect to changes in the contrast will change the minimizer, χ_n^{analyt}, given in Equation (30) to

$$\chi_n=\chi_n^{analyt}+\beta_n d_n, \quad (33)$$

where d_n is the conjugate-gradient direction of the cost functional, Equation (32), with respect to changes of the contrast around the point $\chi=\chi_n^{analyt}$. In view of the previous analytical minimization step, the gradient with respect to the contrast contains only a contribution of the regularization additionally imposed [24]. This simplifies the algorithm. In general, the real parameter β_n is found from a line minimization as the minimizer of the cost functional, Equation (32).

The structure of our multiplicative regularization procedure is such that it will minimize the regularization factor with a large weighting parameter in the beginning of the optimization process, because the value of F_n is still large, and that it will gradually minimize the error in the data and object equations more and more when the regularization factor, F_n^R, remains a nearly constant value. If noise is present in the data, the data error term will remain at a large value during the optimization and, therefore, the weight of the regularization factor will be more significant. Hence, the noise will, at all times, be suppressed in the reconstruction process, and we automatically fulfill the need of a larger regularization when the data contain noise.

5.1 Regularization Factors

Inspired by the edge-preserving algorithms in image restoration [26] and in inverse scattering [27, 28, 29], an efficient regularization factor in the form of a weighted L^2 norm has been developed [25], such that the weighting favors flat parts and non-flat parts of the contrast profile almost equally, viz.,

$$F_n^R(\nabla\chi) = \frac{1}{V}\int_{\mathbf{p}\in D} \frac{\left|\nabla\chi(\mathbf{p})\right|^2 + \delta_n^2}{\left|\nabla_{n-1}(\mathbf{p})\right|^2 + \delta_n^2} dv, \quad (34)$$

where $V = \int_D dv$ denotes the volume of the test domain, *D*. The regularization factor is equal to one when the contrast, χ, is equal to the contrast, χ_{n-1}, of the previous iteration. The positive parameter, δ_n^2, in the numerator takes care of insuring that the regularization factor does not vanish. Further, it also controls the strength of regularization. We therefore have chosen to increase the regularization as a function of the number of iterations by decreasing this parameter δ_n^2. Since the object error term will decrease as a function of the number of iterations, we choose

$$\delta_n^2 = F_D(\chi_{n-1})\tilde{\Delta}^2, \quad (35)$$

where $F_D(\chi_{n-1})$ denotes the object error, Equation (27), and $\tilde{\Delta}$ denotes the reciprocal mesh size of the discretized domain *D*.

Since the regularization factor is equal to one when $\chi = \chi_{n-1}$, the updating of the contrast sources in the inversion algorithm is not changed. Only the updating of the contrast is changed (see Equation (33)), where the parameter β_n follows from minimization of the multiplicative cost functional, Equation (32). Since we deal with a product of two L^2 norms, the minimization of the multiplicative cost functional, Equation (32), can be performed analytically. The cost functional is a fourth-degree polynomial in β. Then, differentiation with respect to β yields a cubic equation with one real root and two complex-conjugate roots. The real root is the desired minimizer, β_n. Further, a careful analysis of this polynomial provides sufficient conditions for convexity of this minimization problem in updating the contrast. In almost all numerical experiments, we have observed that the choice in Equation (35) satisfies these conditions of convexity. The contrast-source-inversion method with this multiplicative regularization factor is abbreviated as the MR-CSI method.

5.2 MR-CSI Reconstruction Examples

Using the MR-CSI algorithms, we discuss some reconstructions from both synthetic and experimental scattered-field data. In particular, we discuss examples from medical imaging and subsurface sensing, where we also consider multi-frequency data.

5.2.1 Concentric Square Cylinders

We again consider our two-dimensional example of the concentric square cylinders (see Figure 2a). We add 10% noise to the synthetic data. In Figure 4, the results of the MR-CSI reconstruction are presented for 128 iterations and 512 iterations, respectively. It is obvious that not only is the noise suppressed in the reconstruction, but so is the band limitation of the reconstructed profile, as well. The differences between the exact profile (see Figure 2a) and the reconstructed results of Figure 4b are hardly visible.

5.2.2 Reconstruction of a Smooth Profile

In order to examine whether the weighted L^2 norm would adversely affect the reconstruction, our next example was a configuration with a smooth contrast. The actual contrast was $\chi = 0.5\sin(\pi x/3\lambda)\sin(\pi y/3\lambda)$, $0 < x, y < 3\lambda$; see Figure 5a. When we used noise-free synthetic data, we observed, from Figures 5a and 5b, no differences between the exact and the reconstructed profiles. However, when we added 10% noise to the data, we observed a step-wise approximation of the profile (see Figure 5c), because small information about the local curvatures was lost in the noise added to the data. Without more information, the present inversion scheme attempts to reconstruct pieces of the profile in such a way that the local variation is minimized.

5.2.3 Microwave Biomedical Imaging

We considered the inversion from TM-polarized electromagnetic data at 2.33 GHz. These data were measured at the Universitat Politecnica de Catalunya, Barcelona, Spain [30], using a scanner consisting of a 12.5 cm radius circular array of 64 water-immersed horn antennas. Only the vertical component of the electric field, parallel to the array axis (the *z* axis) was measured. The 12-measurement procedure recorded the total electric field values at the receiving antennas. If one antenna was transmitting, the fields were measured only with 33 antennas located in front of the active source. The scattered fields were deduced from the total field by subtracting the incident field, measured in

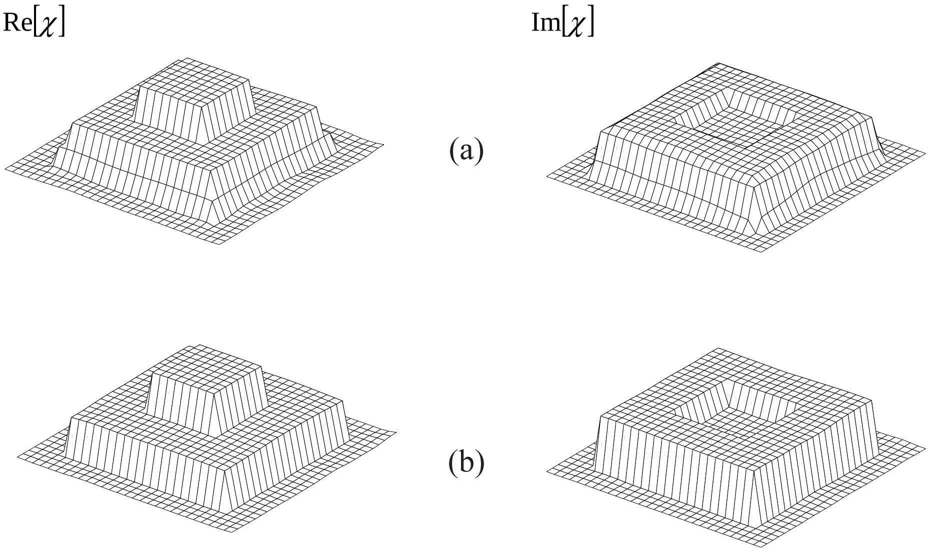

Figure 4. The profile of the concentric squares reconstructed with MR-CSI (10% noise) after (a) 128 and (b) 512 iterations.

the absence of any object. Furthermore, the measured field was calibrated, so that a line source directed in the axial direction could be used as the model of the incident field. We used our two-dimensional inversion method, where we assumed that the unknown object was located entirely within a test domain D of $6.4\lambda \times 6.4\lambda$, where $\lambda = 1.45$ cm was the wavelength in water. The test domain was subdivided into 64 x 64 sub-squares. In the inversion scheme, we took advantage of the a priori information that the complex relative permittivity, ε, should be within the range $0 \le \mathrm{Re}[\varepsilon] \le 80$ and $0 \le \mathrm{Im}[\varepsilon] \le 20$.

We took the data with respect to a real human arm in vivo. We show first the images obtained from our initial estimates, using back propagation. This is approximately identical to the method of spectral diffraction tomography. These results are given in the top plots of Figure 6. The results of the MR-CSI method after 1024 iterations are presented in the bottom plots of Figure 6. The latter images show the positions of the two bones, and the correct values of the muscle (approximately 55 + i17). Conversely, due to the water and tissue attenuation and the reduced dynamic range of the available data, the complex permittivity of the

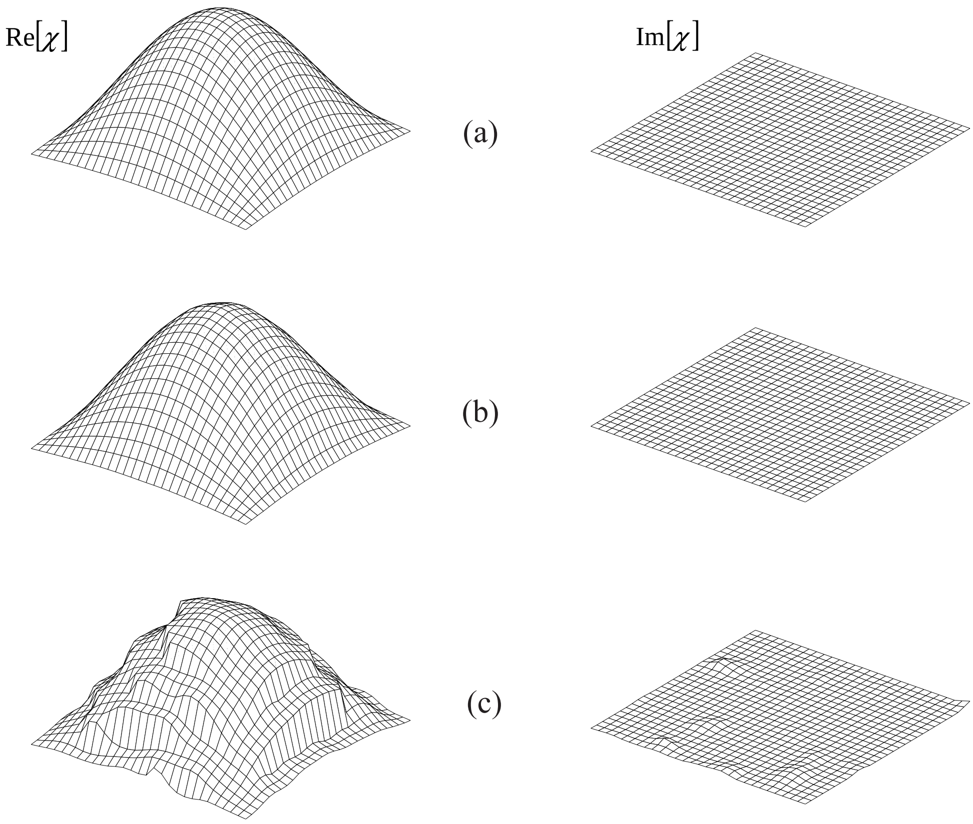

Figure 5. The original sinusoidal profile (a), and the profiles reconstructed with MR-CSI after 128 iterations: (b) without noise, and (c) with 10% noise.

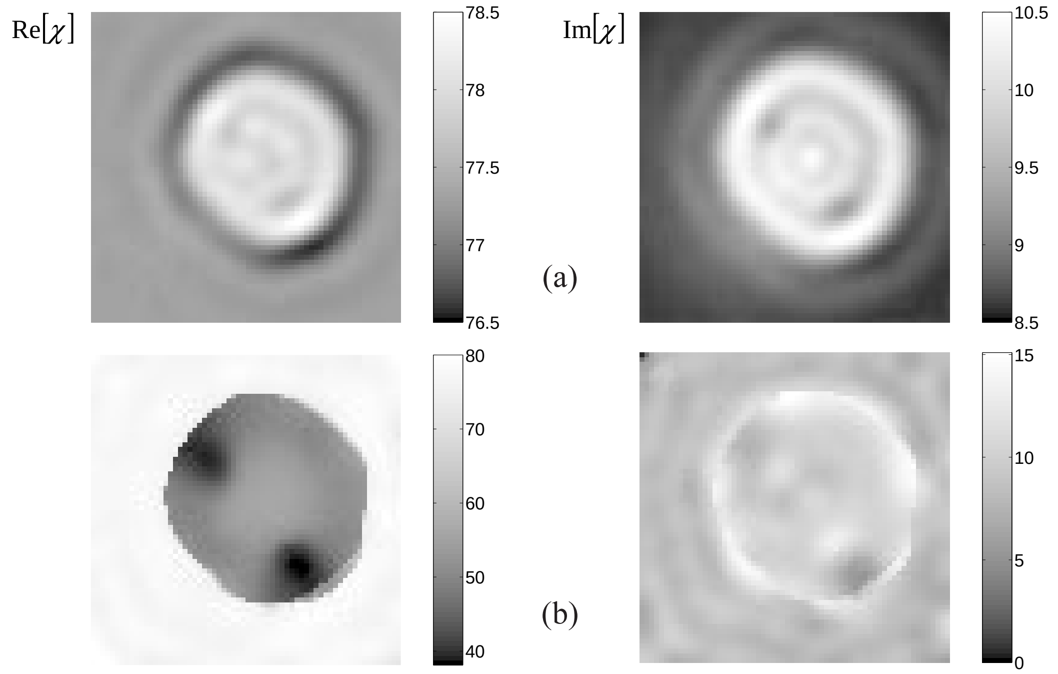

Figure 6. Human forearm images using (a) back propagation and (b) the MR-CSI method.

bones was higher than it should have been (approximately 5.5 + *i*0.6) at the frequency of operation.

5.2.4 Multi-Frequency Experimental Data

Next, we considered the inversion from TM-polarized electromagnetic data measured by the Institut Fresnel, Marseille, France [31]. The transmitting horn antenna was moved on a circle around the object, to 36 locations distributed equidistantly around the object. The receiving horn antenna measured the total and the incident field at 72 different locations around the object. Due to physical limitations, there was a minimal angle between the transmitting and receiving antenna, so that for each illumination, the fields were measured for 49 out of the 72 receiver angles. Further, the measured field was calibrated, so that a line source directed in the axial direction could be used as the model of the incident field. In our two-dimensional inversion algorithm, we assumed that the unknown object was entirely located within a test domain, *D*, of 17 cm by 17 cm. The test domain was subdivided into 63 x 63 sub-squares. We first considered the scattered-field data from an object consisting of two dielectric cylinders. The relative permittivity was estimated to be $3 \pm 0.3 (\chi = 2 \pm 0.3)$. The data were measured at eight frequencies from 1-8 GHz. At the highest frequency, the test domain was about $4.5\lambda \times 4.5\lambda$. Secondly, we considered the scattered-field data from a U-shaped metallic cylinder. The data were measured at eight frequencies from 2-16 GHz. At the highest frequency, the test domain was about $9\lambda \times 9\lambda$.

To reconstruct both objects from these multi-frequency data sets, we had to modify our MR-13 CSI scheme from the single-frequency case to the multi-frequency case. We used the Maxwell model for the frequency dependency of the real and imaginary parts of the permittivity. The modifications are straightforward: see [32]. The reconstructed images are presented in Figure 7. The reconstruction of the two dielectric cylinders is presented on the left-hand side. Note that the contrast was purely real, with a top value of $\chi \approx 2$. The reconstruction of the metallic cylinder is presented on the right-hand side of Figure 7. From the images, we directly observe that the object is a U-shaped, highly conductive object. This distinction between a purely dielectric object and a highly conductive object was better than what we have presented earlier [32], because we here used the weighted L^2 norm as the regularization factor, while in [32] we used the L^1 norm of total variation.

5.2.5 Subsurface Sensing

Our next example was devoted to two-dimensional subsurface sensing, where *x* is the horizontal coordinate and *z* is the vertical coordinate. Here, the fundamental problem is that we had measurements on a line at one side of the domain of interest. Although uniqueness is a problem from a theoretical point of view, we applied our optimization method without some essential changes. So far, in all examples we have used a homogeneous background with the two-dimensional free-space Green's function. In view of the large difference between the permittivities of air and soil, we used a two-media background, with a planar air-soil interface at $z = 0$, $-\infty < x < \infty$. The two-dimensional Green's function was readily obtained in terms of a Sommerfeld Fourier integral.

We assumed a contrasting domain, with some horizontally layered domains and some local inhomogeneities. In addition, the actual air-soil interface was modeled with some roughness. This contrasting domain had dimensions of 60 cm in the horizontal direction and 16 cm in the vertical direction. We subdivided this test domain into a mesh of 64x32 sub-squares. The original permittivity and conductivity distributions are shown in Figure 8a.

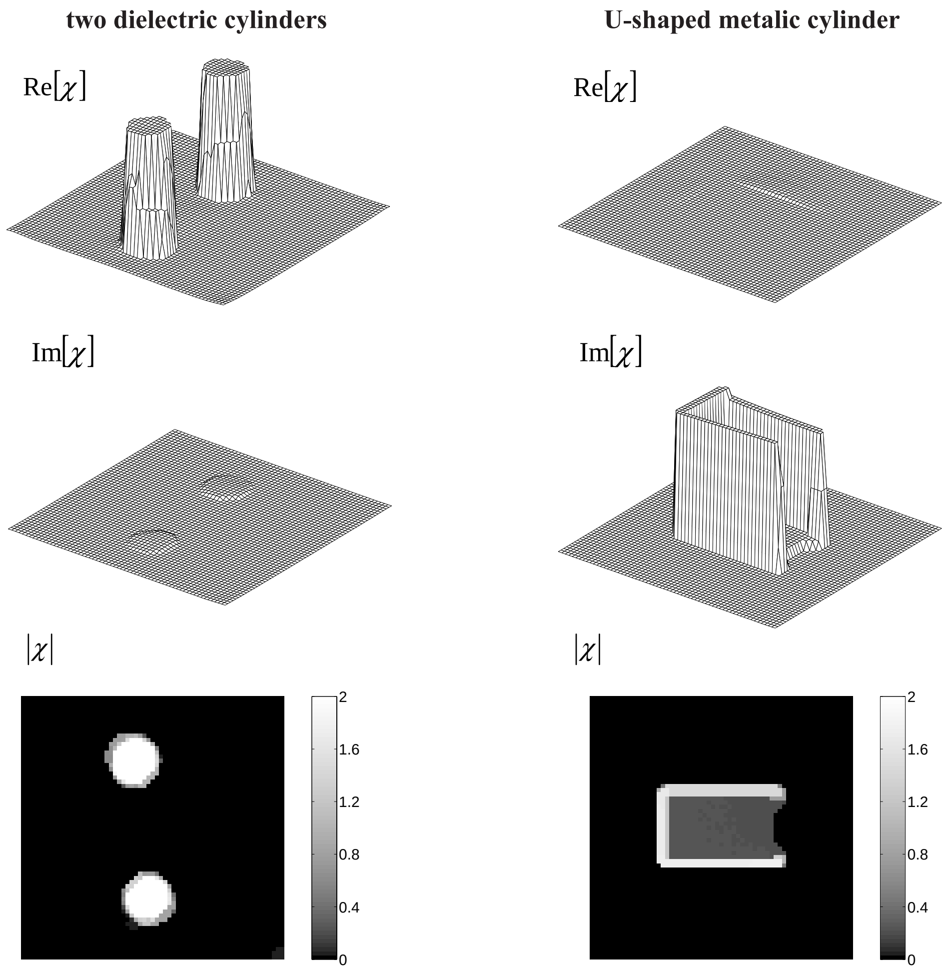

Figure 7. The reconstruction of the two dielectric cylinders (left) and the U-shaped metallic cylinder (right) from experimental data.

At $z = 0$, 16 sources were distributed equidistantly with a spacing of 2 cm. For each illumination (by a single source at $z = 0$), the fields were measured by 32 receivers, distributed equidistantly with a spacing of 1 cm. The data were generated synthetically. We considered a multi-frequency source, with 10 frequencies, from 0.25 up to 2.5 GHz. We added 10% random noise to the data. In the inversion, we again used the Maxwell model for the frequency dependence of the contrast. The results of the MRCSI reconstruction are given in Figure 8b. The layering and the location of the inhomogeneities were reconstructed well enough; the shape of the rough interface between the air and soil was especially imaged very well. Studying the images of the permittivity profile and the conductivity distributions, it seems that the permittivity had more resolution than the conductivity. One explanation of this is the observation that the propagating character of the wave field (mainly determined by the permittivity) has better imaging properties than the diffusive character of the wave field (mainly determined by the conductivity).

6. Three-Dimensional Electromagnetic Inversion

The ultimate goal of inverse scattering is to deal with three-dimensional objects. Therefore, as a last example, we considered the three-dimensional version of our configuration of Figure 3a, consisting of concentric cylinders in vacuum [33]. We considered the single-frequency case with wavenumber $k_0 = \omega\sqrt{\varepsilon_0 \mu_0}$, where ε_0 and μ_0 denote the permittivity and permeability in vacuum, respectively. As shown in Figure 9a, the three-dimensional configuration consisted of an inner cube, λ by λ by λ, with electric contrast $\chi = 0.6 + 0.2i$, surrounded by an outer cube, 2λ by 2λ by 2λ, with electric contrast $\chi = 0.3 + 0.4i$. There was no contrast in the permeability. The measurement domain, *S*, was chosen to be either a circle of radius 3λ at $z = 0$, or three circles at $z = -\lambda, 0, \lambda$ (see Figure 9). In the first measurement setup, 30 stations were located uniformly on the circle, with each station serving as a vertical-magnetic-dipole source, and all stations acting as receivers, measuring the three components of the magnetic-field vector. In the second measurement setup, on each circle there were 10 sources and 30 receivers. Hence, in both measurement setups, the total number of data points was the same. The test domain, *D*, was a cube with dimensions of 3λ by 3λ by 3λ.

We measured the magnetic-field components in this three-dimensional problem, so that the data equation was the magnetic-field representation,

$$\mathbf{H}^{sct}(\mathbf{p}) = -i\omega\varepsilon_0 \nabla \times \int_{\mathbf{q}\in D} G(\mathbf{p},\mathbf{q})\,\chi(\mathbf{q})\,\mathbf{E}(\mathbf{q})\,dv, \qquad (36)$$

for $\mathbf{q} \in S$, while the object equation was the electric-field equation,

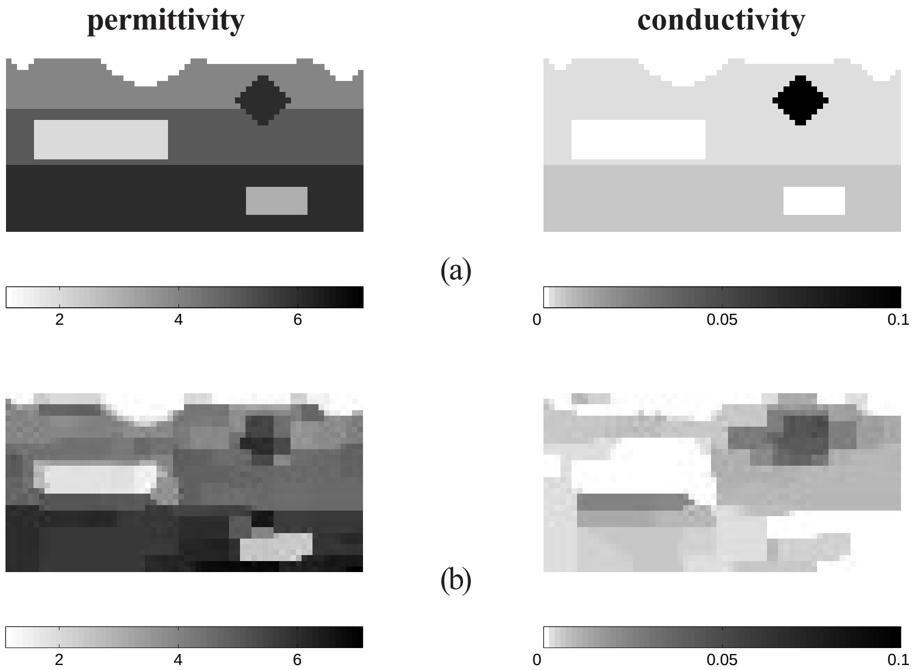

Figure 8. The original subsurface profile with a rough air-soil interface (a), and its MR-CSI image (b).

$$\mathbf{E}(\mathbf{p}) = \mathbf{E}^{inc}(\mathbf{p}) + \left(k_0^2 + \nabla\nabla\cdot\right)\int_{\mathbf{q}\in D} G(\mathbf{p},\mathbf{q})\chi(\mathbf{q})\mathbf{E}(\mathbf{q})\,dv, \tag{37}$$

for $\mathbf{q} \in D$. Here, $G(\mathbf{p},\mathbf{q}) = \exp\left(ik_0|\mathbf{p}-\mathbf{q}|\right)/4\pi|\mathbf{p}-\mathbf{q}|$ is well-known free-space Green's function.

In the inversion, the test domain, *D*, was discretized into 30 x 30 x 30 sub-cubes. In Figure 10a, we present the original profile in two orthogonal cross sections. The reconstructed images after 1024 iterations are given in Figures 10b and 10c, when we had one measurement ring and three measurement rings, respectively. Note that with one ring of measurements, only the boundary of the outer cube was reconstructed. More details are visible in the reconstructed profile when three rings of measurements were used, especially in the horizontal cross section: an almost ideal image was obtained. This is highlighted in the surface plots of Figure 11, where the original profiles of the contrast in the horizontal cross section (Figure 11a) are presented. The reconstructions are given in Figures 11b and 11c, for one measurement ring and three measurement rings, respectively.

This example shows that inversion of a three-dimensional object can be carried out slice by slice, similar to tomographic inversion. However, measurements should be made not only in the plane of the slice, but also in the neighboring planes on both sides of the particular slice of observation. It is also noted that measurement of more field components is a prerequisite. Measurement of only one component significantly reduces the resolution of the image [7].

7. Conclusions

We have reviewed a number of algorithms to solve the nonlinear inverse-scattering problem at hand. Although there are many fundamental problems to solve, both theoretically and numerically, we have shown that a well-designed optimization method, e.g., the "Multiplicative Regularized Contrast Source Inversion" method, makes the "blind" reconstruction of realistic configurations from scattered-field data feasible. In view of the efficiency and robustness of the present algorithms, we conclude that, in the near future, nonlinear inversion methods will have a prominent position for handling full vectorial three-dimensional scattered-field data.

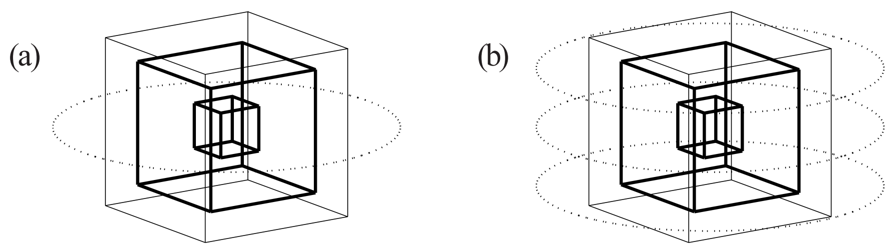

Figure 9. Concentric cubes with (a) one ring of sources and receivers, and (b) three rings of sources and receivers.

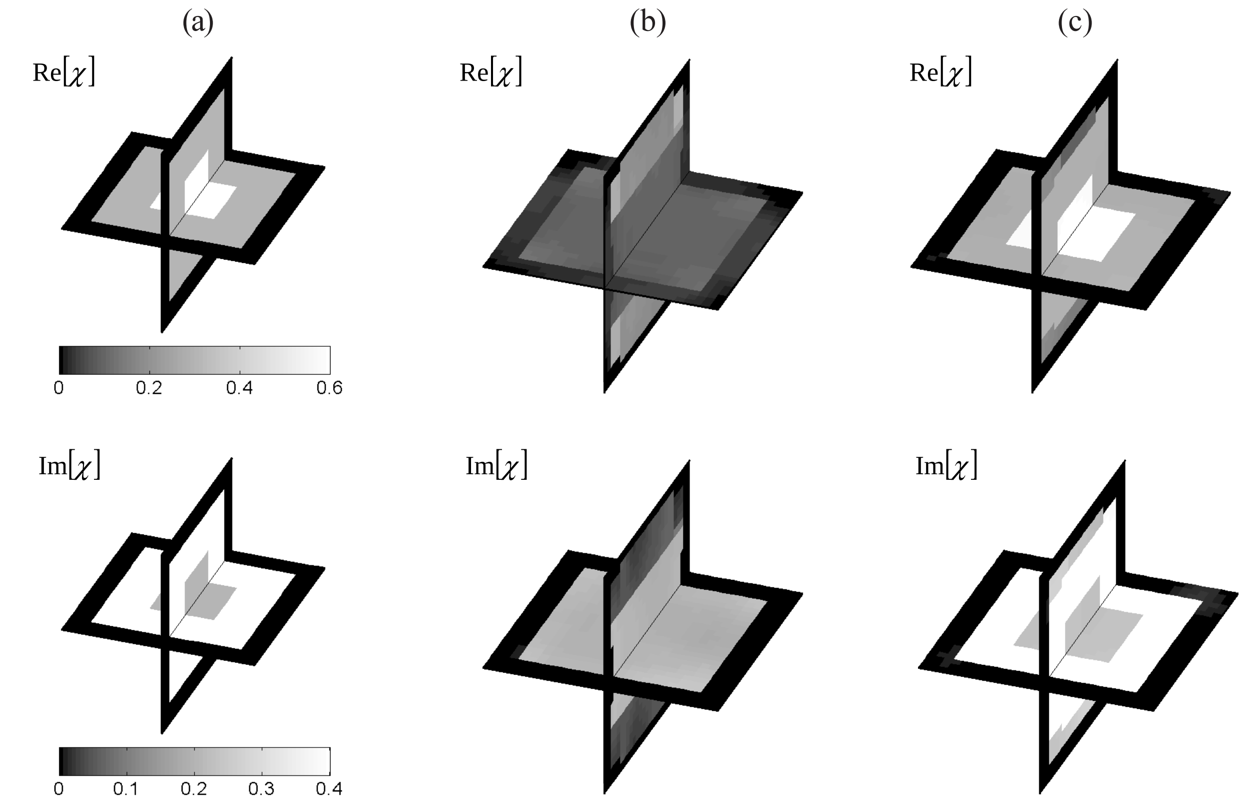

Figure 10. Orthogonal cross-sections of the concentric square cubes: (a) the original profile, (b) the reconstruction with one ring of sources and receiver, and (c) the reconstruction with three rings of sources and receivers.

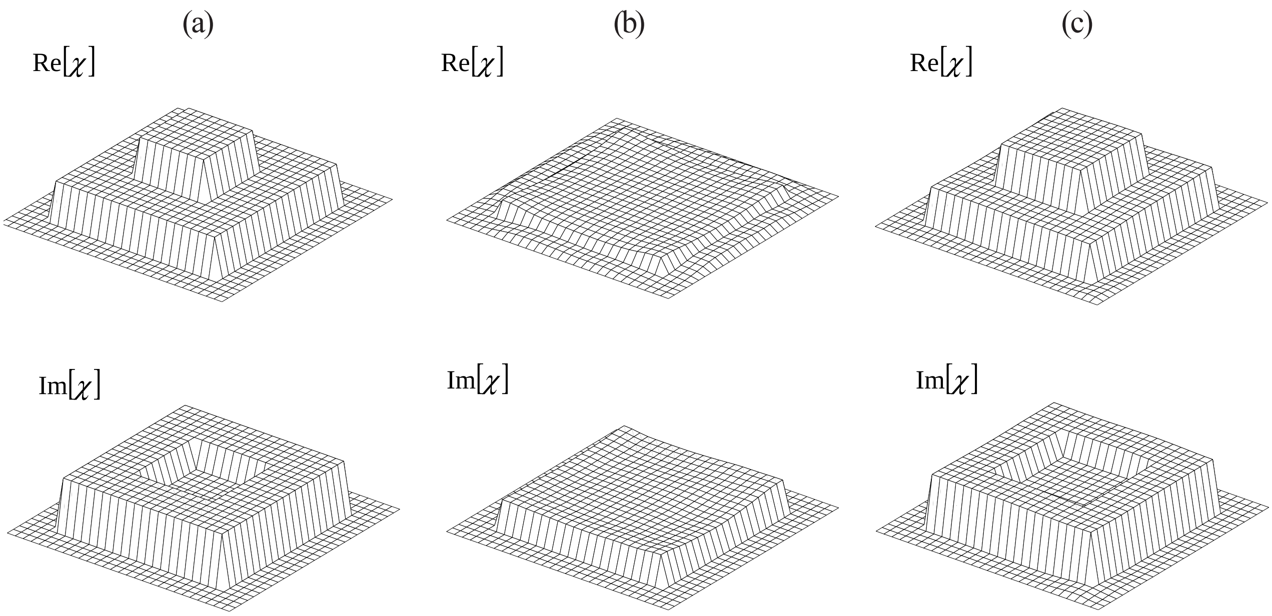

Figure 11. The horizontal cross section of the concentric square cubes: (a) the original profile, (b) the reconstruction with one ring of sourcesand receivers, and (c) the reconstruction with three rings of sources and receivers.

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Radio-Occultation Projects in Space Programs of Japan

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Abstract

The history of radio-occultation studies in Japanese spacecraft projects began in 1985, when the Institute of Space and Astronautical Science (ISAS) realized the Sakigake mission, targeted to explore the solar wind and its interaction with the comet Halley. The next project was accomplished through the cooperation of NASA and ISAS in the investigation into the Neptune atmosphere, during the Voyager mission. In July of 1998, the NOZOMI spacecraft was launched toward Mars, with the primary objective of the program being to study the interaction of the Martian upper atmosphere with the solar wind. Among its experiments was the dual-frequency measurement. Three spacecrafts of the SELENE mission, which is a joint space program of ISAS and the National Space Development Agency of Japan (NASDA), will become the orbiters of the moon in 2005. The radio-occultation technique will be applied for the investigation of the plasma clouds above the lunar surface. Recently, another ISAS project, "Planet-C," has been officially approved. In this project, the spacecraft should be driven into orbit around Venus in 2009, and its radio communication system will be used for the exploration of the Venusian atmosphere and the solar corona.

1. Introduction

The radio-occultation technique was developed during several decades of solar-system exploration. The traditionally employed method of retrieving atmospheric profiles from radio-occultation measurements is based on the Abel inversion and Geometric Optics [1, 2, 3]. Later, a new method of data processing, based on scalar diffraction theory, was developed, to consider the effects of multipath propagation [4, 5]. The changes in the phase, amplitude, and polarization of the waves are also caused by wave propagation in inhomogeneous interplanetary plasma [6, 7, 8].

In radio-occultation measurements, the perturbations of radio signals propagating from a transmitter to a receiver are used to study the medium of interest, such as planetary atmospheres and interplanetary plasma. To control spacecraft, ISAS constructed a 64-meter-diameter antenna at the Usuda Deep Space Center (UDSC), in Japan. Among the facilities developed was a signal recording system for radio occultation (Figure 1). Having at its disposal these ground facilities and realizing its own spacecraft missions, Japan successfully started various scientific space programs. Radio-occultation experiments are included in those missions as an important means of space exploration. This article summarizes the past and future ISAS programs of radio-occultation experiments.

2. Previous Missions

The first radio-occultation experiment in Japan was accomplished using a first Japanese interplanetary spacecraft Sakigake, which was launched in 1985 as a member of the international comet Halley armada. The Sakigake project was targeted to directly measure the solar wind, magnetic fields, and plasma waves in interplanetary plasma, especially during the comet Halley encounter, although the distance between Sakigake and the comet Halley was quite far, about 7×10^6 km [9]. Sakigake also conducted radio-occultation measurements of the solar corona during the solar conjunction in 1988. The frequency broadening observed with Sakigake during this period is consistent with that observed before by other interplanetary spacecraft (Figure 2).

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[Editor's note: This paper is invited.]

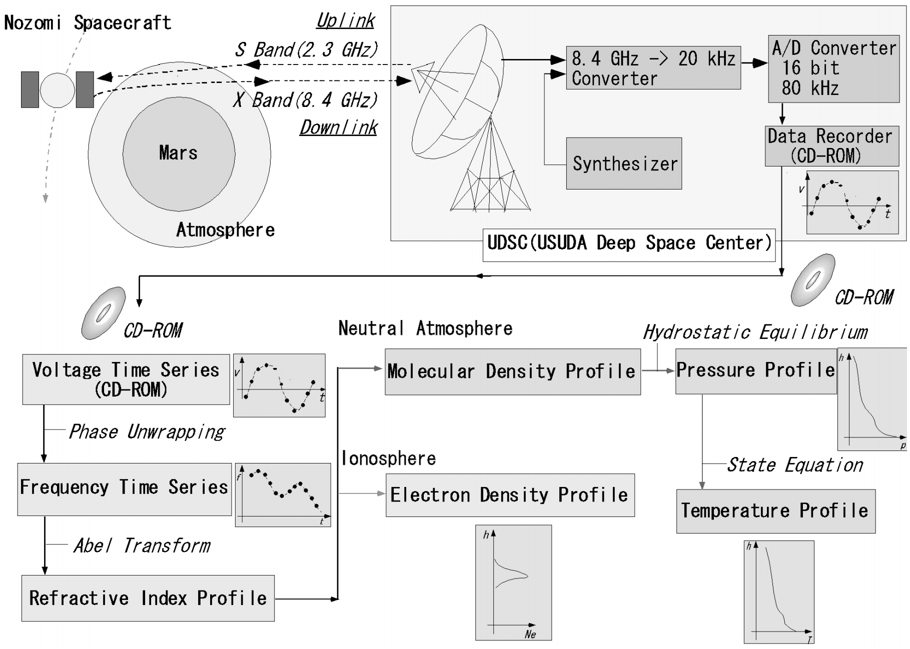

Figure 1. The data-recording system at UDSC, and the data-processing procedure for radio-occultation experiments.

In 1989, during the Neptune encounter of Voyager 2, ISAS cooperated with NASA in carrying out a radio-occultation experiment on Neptune's atmosphere. The radio occultation revealed the thermal structure of the neutral atmosphere, and the electron-density profile in the ionosphere [10]. The accuracy of the profiles was improved by coherently arraying the signals recorded simultaneously at different stations, including UDSC [11].

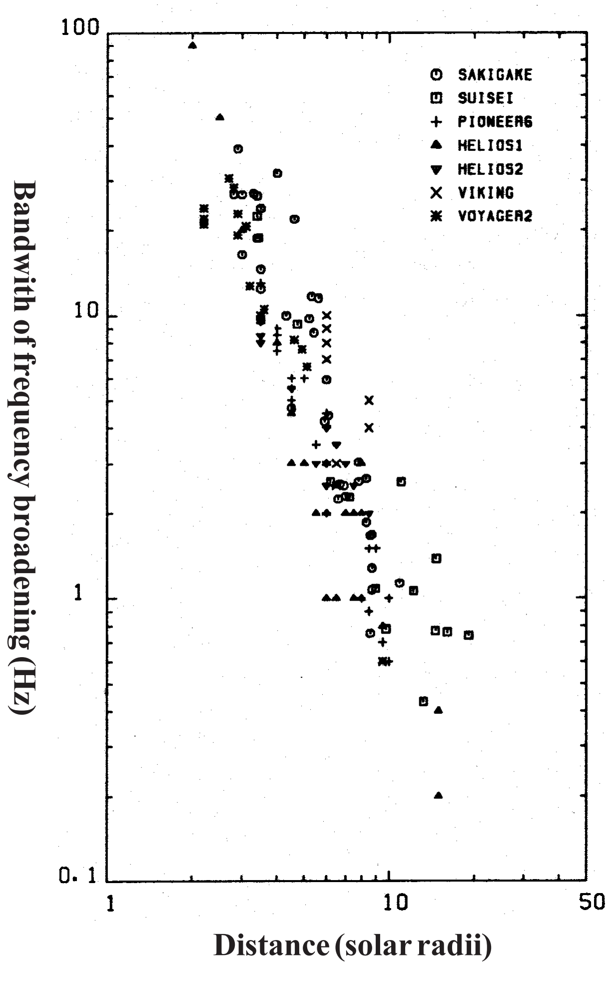

Figure 2. Frequency broadening observed during solar conjunctions using Sakigake and other interplanetary spacecraft, as a function of the distance from the center of the Sun to the ray path.

3. Future Missions

In the near future, radio-occultation experiments will be performed on missions to Mars, the moon, and Venus. These radio-occultation projects are briefly described below.

3.1 NOZOMI, a Mars Orbiter

The NOZOMI spacecraft was launched in 1998, and is scheduled to arrive at Mars in 2004. The primary objective of the mission is to reveal the interaction between the Martian ionosphere and the solar wind. Radio occultations of the Martian atmosphere are planned after the orbital injection of the spacecraft. The spacecraft was supplied with a dual S- and X-band frequency transmitter for performing radio-occultation experiments, aimed at observing the thermal structure of the neutral atmosphere and the electron-density profile of the ionosphere.

High-vertical-resolution profiles of temperature, obtained by radio occultation, are useful for meteorological study. The Viking radio occultation showed that during global dust storms, the thermal structure changes strongly near the surface [12]. More recently, the radio occultation experiments with Mars Global Surveyor (MGS) have given us many insights into the Martian atmosphere, such as the temporal variation of the radiative-convective boundary layer near the surface, distinctive meridional gradients of pressure at low altitudes, and the presence of atmospheric waves, such as gravity waves, planetary waves, and thermal tides [13, 14]. The MGS observations also indicated the influence of thermal tides on the variation of the height of the ionospheric peak [15], suggesting a close coupling between the neutral atmosphere and the ionosphere.

Among the unsolved problems of the Martian ionosphere is the source of nightside plasma. In contrast with the dayside ionosphere, which has been observed many times, the nightside ionosphere is not well characterized, due to sparse sampling [16, 17]. Since very few data are available, the ionization mechanism of the nightside ionosphere of Mars is still unsolved. Some hypotheses of the ionization were proposed from the point of view of electron precipitation [18, 19] and transport from the dayside [20]. It is expected that NOZOMI's radio-occultation measurement will provide new data to improve the understanding of the nightside ionosphere with the aid of simultaneous in-situ measurements.

Using the NOZOMI spacecraft, a radio-occultation experiment on the solar corona was performed from December, 2000, to January, 2001. During the observation period, the distance from the ray path to the solar surface ranged from 12 to 37 solar radii. Unfortunately, it was impossible to implement the dual S- and X-band frequency configuration, because only the X-band transmitter is working now, due to onboard trouble. Therefore, the two-way radio-propagation scheme was used: the S-band uplink was generated using the ultra-stable oscillator (the Allan variance is about 10^{-15}) at UDSC, and it was converted into the X-band downlink onboard the spacecraft. Examples of the phase fluctuation for 37, 26, and 12 solar radii are shown in Figure 3. The results of detailed analyses will be reported elsewhere in the near future.

3.2 SELENE, a Lunar Orbiter

The primary objectives of the SELENE mission, which is a joint space program of ISAS and NASDA, are to study the lunar origin, evolution, and environment. The radio-occultation experiment using the SELENE spacecraft, the launch of which are scheduled in 2005, aims to study the charged-particle regions near the lunar surface.

The first radio occultation of the moon was performed with the Pioneer 7 spacecraft, using dual-frequency (49.8 and 423.3 MHz) beacons [21]. At that time, no plasma cloud with an electron density greater than 4×10^7 m^{-3} was detected. On the other hand, the dual-frequency (0.9 and 3.7 GHz) occultation with the Russian spacecraft Luna 19 and 22 showed a total electron content of the order of 10^{14} m^{-2} at altitudes up to 10 km [22] above several regions

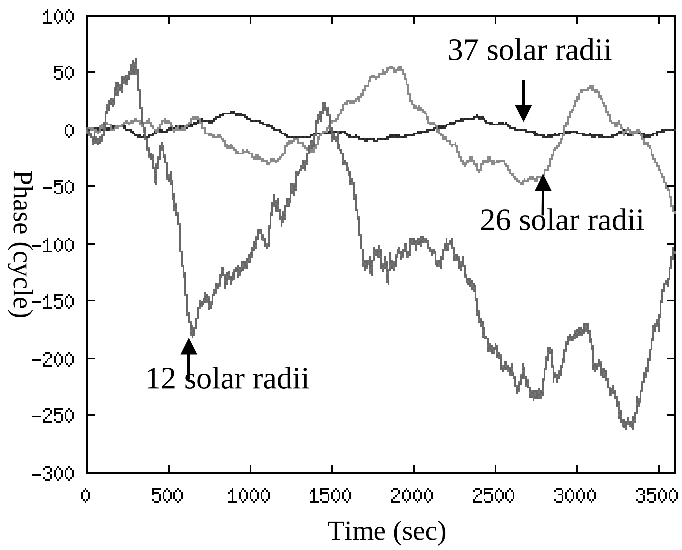

Figure 3. A part of the time series of the phase fluctuation in the two-way signal (S-band uplink and X-band downlink) observed during a solar conjunction using the NOZOMI spacecraft. The numerals indicate the distance between the solar surface and the ray path.

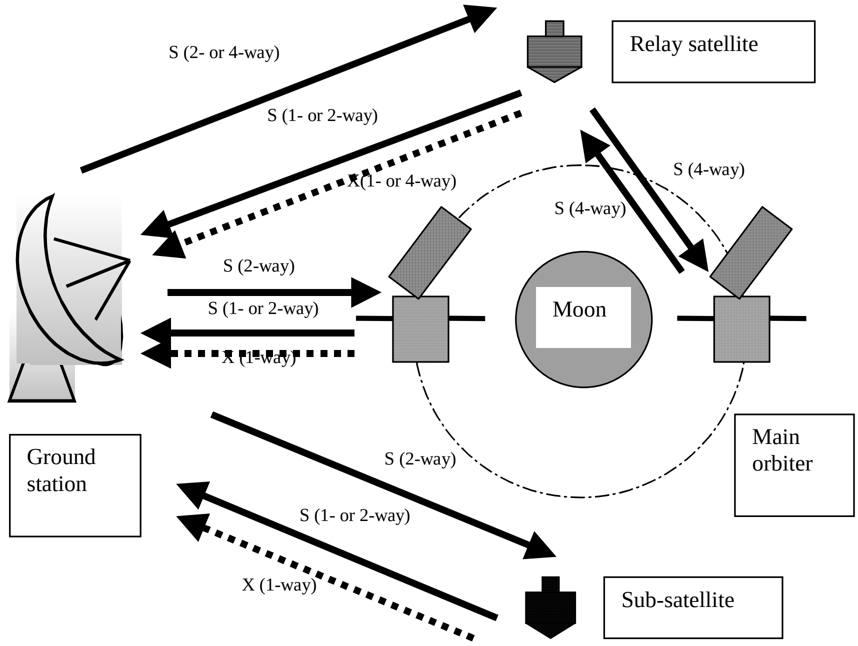

Figure 4. A schematic of the radio-communication system of the SELENE mission. The solid and broken arrows indicate the S and X bands, respectively. The relay satellite has an oscillator for a VLBI experiment, and a transponder for four-way communication. The sub-satellite has an oscillator for VLBI, and a transponder for two-way. The relay satellite and sub-satellite can emit S and X bands simultaneously in one-way mode

of the lunar surface, corresponding to an electron density of ~10^9 m^{-3} for the case of spherical symmetry. During the Lunar Prospector mission, "an intriguing magnetic anomaly on the moon's surface has been found that can stand off the solar wind, thus creating the smallest known magnetosphere, magnetosheath and bow shock system in the Solar System" [23]. Maybe the next step will be the discovery of "local mini-ionospheres" near the moon's surface.

The radio-communication system of the SELENE mission, shown in Figure 4, provides various possibilities for conducting radio occultation. The mission is composed of a main orbiter, a relay satellite, and a sub-satellite for a VLBI (very long baseline interferometry) experiment. Radio occultation will basically be performed using the coherent S- and X-band downlink from the main orbiter. Other suitable configurations, using the relay and sub-satellites for the detection of the charged particle layer, are now being planned.

3.3 Planet-C, a Venus Orbiter

The Planet-C mission, which has recently been officially approved as an ISAS project, is devoted to studies of Venus. The spacecraft should be driven into orbit around Venus in 2009. The primary objective of the mission is to investigate the atmospheric dynamics of Venus, using optical remote sensing and radio occultation. The radio-occultation technique has been utilized to study the thermal structure of the Venusian atmosphere [24]. Recently, radio occultation has also revealed the vertical distribution of sulfuric-acid vapor [25], and the presence of internal gravity waves [26]. The Planet-C mission will provide new information on the three-dimensional structure of Venusian meteorology, by combining the high-vertical-resolution profiles taken by radio occultation and the high-spatial-resolution imagestaken by onboard optical instruments.

The radio communication system of Planet-C will use X band in both the uplink and the downlink. The X-band signals can also be employed for occultation measurements of the solar corona in the range of impact parameter below five solar radii, in an attempt to get information on the parameters of the solar wind, in particular, on the characteristic scale of magnetohydrodynamic turbulence. Those results would be useful in solving the problem of the origin of the solar-wind plasma irregularities: generation by the Alfvén waves propagating from the transition-layer base, or generation by local instabilities [27].

4. Concluding Remarks

Past and future projects of radio occultation in Japan have been described. The projects cover the exploration of planetary atmospheres, the solar wind, and their interaction. The long history of radio occultation has shown the importance of the method, its advantages and disadvantages. The method is regarded as a powerful tool for space investigations in future missions, especially for exploring regions unattainable by other means.

The potential for space programs of Japan is seriously limited by the locations of the deep-space tracking antennas. To increase the opportunities in space research, several deep-space tracking antennas located at different longitudes are required. International collaboration in radio science is strongly needed.

5. Acknowledgement

In order to prepare the present paper, much useful information was given by N. A. Savich, of the Institute of Radio Engineering and Electronics of Russian Academy of Science. We especially thank T. Takano, Z. Yamamoto, and T. Ichikawa, of ISAS, for developing the radio-occultation system, and for providing useful information.

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Effects of Water Vapor and Liquid Water on Microwave Absorption, and their Application

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Abstract

The dependence of microwave absorption on water vapor and liquid water is discussed. The effect of liquid water on allocating a window frequency is found to be more important than that of water vapor. For extreme cases, such as Calcutta, conventional choices are not optimal. It is also revealed that the window frequency lies within 25-28 GHz over Calcutta, instead of the conventional window frequency at 31.4 GHz.

1. Introduction

It is commonly believed that the spectral behavior of atmospheric constituents in the microwave or millimeter waveband offers a good opportunity for the measurement of atmospheric constituents, such as water vapor, liquid water, temperature, etc. A number of publications are available in this regard [1-8]. The radiometric measurements of water vapor at 22.235 GHz may be mentioned in this connection. This spectral line is rather weak, which implies that radiation emitted by water-vapor molecules at higher altitudes will only be slightly attenuated when it reaches the Earth's surface. However, the presence of cloud liquid in the atmosphere makes the situation more complicated. The radiative properties of water vapor and liquid water are significantly different, as is evident from Figure 1 [7]. Because of the difference in spectral behavior, it is possible to separate water vapor and liquid water effects by measuring atmospheric attenuation at an additional frequency, away from the water-vapor absorption peak occurring at 22.235 GHz. However, in the present context, the effects on the microwave absorption, due to the presence of water vapor and non-precipitable liquid water, are discussed with a view to finding out the spectral minima between the principal atmospheric lines occurring at 22.235 and 60 GHz.

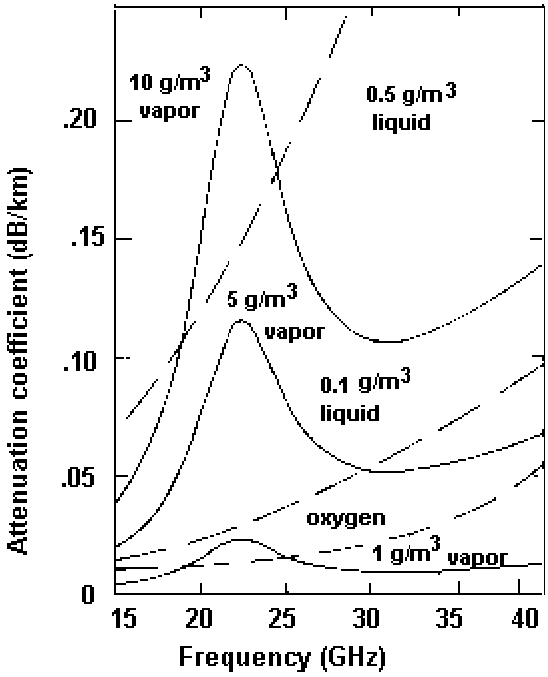

Figure 1. The atmospheric attenuation coefficient as a function of frequency for different densities of water vapor and liquid water [7].

2. Analyses and Results

Radiosonde data over Calcutta (Latitude 22°32' N; Longitude 88°22'E) for the year 1996 were used to calculate water-vapor attenuation coefficients (dB/km) for 1 to 40 GHz. For this purpose, the well-known Millimeterwave Propagation Model, as described by Liebe [9], was used to find the attenuation coefficient (dB/km) for different altitudes over Calcutta, at different frequencies within the 1-40 GHz band. The integrated attenuation (dB) within the height

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limit of 0-10 km was calculated using Romberg's integration method. It was also assumed that beyond 10 km, the water-vapor concentration has a negligible effect on the spectrum [10]. While calculating the attenuation and presenting the microwave spectrum in the band from 1 to 40 GHz, radiosonde data for a particular day and time (June 15, 1996) were chosen, so as to get an idea of the spectrum in the monsoon months (having a large ambient humidity, ~80-90%) over Calcutta. Similarly, the water-vapor density (g/m^3) at different altitudes was used to find the water-vapor content. The choice of this particular day and time allowed us to calculate the spectrum for a particular value of water-vapor content of about 76 kg/m^2. Care was also taken to include the effect of the oxygen contribution while presenting the spectrum (Figure 2). The attenuation at different frequencies (1-40 GHz), due to cloud liquid-water content, *W*, was also studied as described by Westwater [4], using the expressions detailed by [11]. The integrated liquid-water content was then varied from zero to a maximum possible amount of 2 kg/m^2 over a tropical station like ours (refer to Figure 2). It is clear from the figure that for a change of 2 kg/m^2 liquid-water content, the first water-vapor maximum is approximately invariant, while the minimum has been shifted from 31.448 GHz to 28.381 GHz for which a corresponding change in brightness temperature of about 46 K occurs, which is equivalent to 0.75 dB. For this purpose, the brightness temperature, $T_a(K)$, has been converted to total attenuation, *A* (dB), by using the relation [5]

$$A = 10\log_{10}\frac{T_m - T_c}{T_m - T_a}, \qquad (1)$$

where T_m is the mean atmospheric temperature, and T_c is the equivalent temperature of the cosmic background radiation, which is considered to be 2.7 K [6]. For tropical latitudes like Calcutta, the value of T_m is found to be higher than that at temperate latitudes, due to higher temperature and large water-vapor content [12]. The mean atmospheric temperature has been calculated with the help of the known vertical profile of atmospheric temperature and the corresponding vertical profile of attenuation coefficient. It is also observed that at 22.235 GHz, the mean atmospheric temperature is related to the ground temperature, T_s, obeying the relationship [2]

$$T_m = a + bT_s \qquad (2)$$

The values of *a* and *b* have been presented by Mitra et. al [13] for different months over Calcutta. With this idea of values for monsoon months, the value of attenuation, *A*, has been derived.

Again, an attempt was also made to find out the effect of water vapor only on the microwave absorption, keeping the liquid-water content constant. Figure 3 presents the spectrum for liquid-water content set to zero value, although this case is the lower limit. But, still, for the present purpose, we have varied the water-vapor content through 36 kg/m^2, keeping the liquid-water content zero. It is observed from Figure 3 that the minimum lies at 31 GHz in both cases, but a corresponding brightness-temperature change of about 10 K occurs, for which the attenuation change is 0.11 dB. So, we are in a position to conclude that the effect of liquid water is more prominent than that of water vapor in determining the minimum in the spectrum at a tropical latitude like that of Calcutta.

Here, for the sake of convenience, the daily variation of estimated liquid-water content, *W*, [14] over Calcutta is presented in Figure 4. This will provide some idea for choosing the maximum bearing liquid-water content over Calcutta as being about 2 kg/m^2.

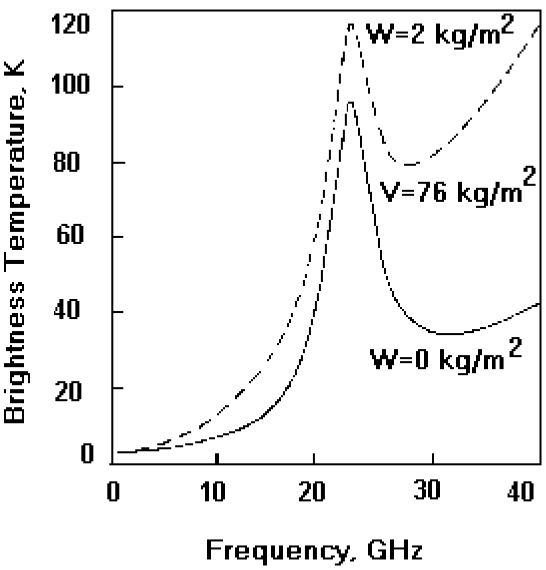

Figure 2. The brightness temperature as a function of frequency (0-40 GHz), for a particular value of water-vapor content (76 kg/m^2) and liquid-water content (2 kg/m^2 and 0 kg/m^2).

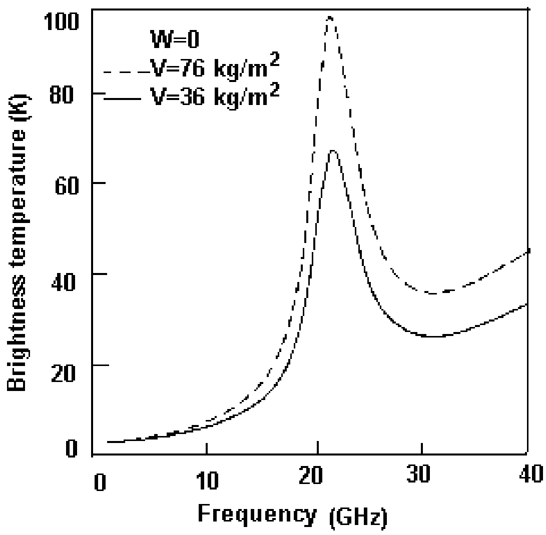

Figure 3. The brightness temperature as a function of frequency for constant liquid-water content, and variable values of vapor content: 36 and 76 kg/m^2.

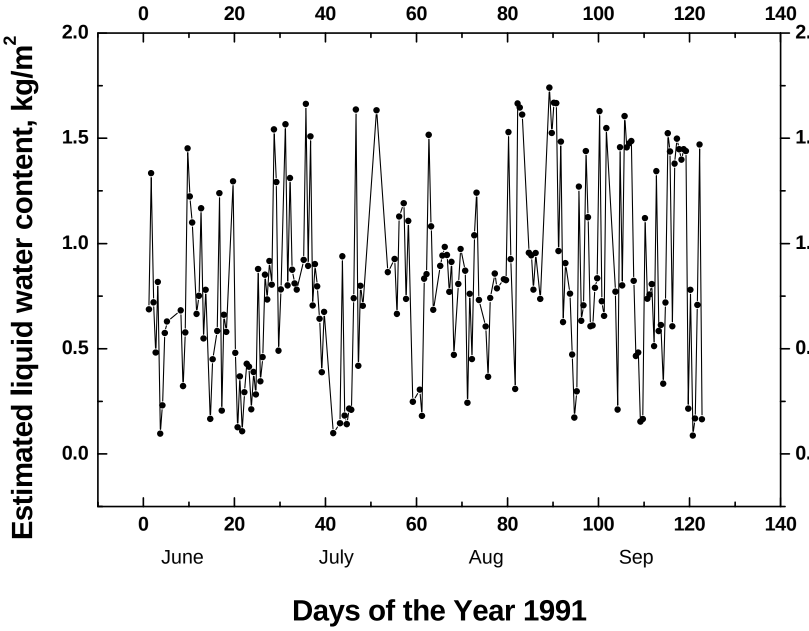

Figure 4. The daily variation of liquid-water content over Calcutta during monsoon months [14].

An attempt has also been made to present the variation of the window frequency where the attenuation is a minimum between the spectral line or band features occurring at 22.235 and 60 GHz, corresponding to different amounts of liquid-water content over Calcutta in Figure 5.

The whole above idea is presented in Table 1, keeping the water vapor set to different values for different days and time. The table shows that the presence of liquid-water content determines the minimum. However, the constancy of the weighting function [K(g/m^3)km^{-1}] with height at the desired frequency provides the potential for application of that frequency. Westwater et al. [15] showed that below

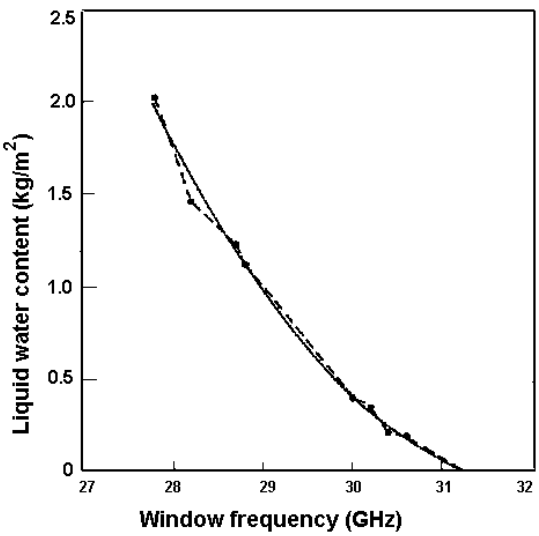

Figure 5. The variation of the window frequency in the millimeter-wave band for different values of liquid-water content.

about 5 km, the water-vapor and liquid-water weighting functions at 20.6 and 31.65 GHz are nearly constant with height. This shows that the variations in brightness temperature are primarily affected by variations in the column-integrated amounts of vapor and liquid, as these are mostly abundant below about 5 km. However, it was noted earlier that the variability of water vapor over Calcutta is very large, which ultimately results in the large variation of brightness temperature. Under the circumstances, the frequencies suggested by Westwater [15] may not be suitable over a tropical station like Calcutta.

It is a common practice to use one of the frequencies lying at the peak of an absorption line to measure the density of a substance. In our case, since we are limiting ourselves to the measurement of water vapor, the choice of 22.235 GHz seems to be optimum. Here, at this frequency, the signal-to-noise ratio is maximum, provided the ambient pressure and temperature are constant. But in practice, when pressure and temperature are variable, the selection is not optimum.

For this purpose, a computational program has been written to find water-vapor weighting functions [6] at each frequency (up to three decimal places), with a step size of 0.001 GHz, in the 20-25 GHz band. Now, using the upper-air data over Calcutta provided by the India Meteorological Department, Government of India, it can be observed that the weighting function is not constant with height at each frequency, as desired. Hence, the difference between the maximum and minimum values of the weighting function at each frequency has been calculated. It is obvious now that the lesser the difference, the steeper is the weighting function, and vice-versa. Keeping this idea in mind, plots of frequency versus this difference have been prepared (Figure 6) for the months of January and July, 1996, as these two months are found to be the maximum and minimum, respectively, bearing vapor over Calcutta.

	Liquid kg/m²	Vapor kg/m²	Peak Frequencies (GHz)	Window Frequencies (GHz)
A	0	76.0	22.416 60.375 118.756 183.336	31.448 75.212 124.578 211.0
	1	76.0	22.438 60.376 118.757 183.336	29.435 72.811 123.855 209.28
	2	76.0	22.458 60.377 118.759 183.336	28.381 71.477 123.204 207.61
B	0	77.4	22.472 60.375 118.755 183.340	31.475 74.975 124.5 210.88
	1	77.4	22.50 60.375 118.760 183.340	28.515 72.69 123.655 208.990
	2	77.4	22.530 60.375 118.760 183.340	28.46 71.485 123.135 207.39
C	0	24.84	22.611 60.365 118.755 183.345	30.525 82.115 128.05 213.295
	1	24.84	22.610 60.365 118.755 183.345	26.98 74.815 125.51 208.5
	2	24.84	22.755 60.365 118.760 183.345	25.715 72.595 124.185 205.265
D	0	27.77	22.449 60.365 118.755 183.337	30.695 82.236 128.065 213.139
	1	27.77	22.5304 60.376 118.757 183.337	27.370 74.838 125.418 208.502
	2	27.77	22.614 60.369 118.760 183.337	26.172 72.651 124.504 205.402

A: Date: 15.07.1991; Time: 17:00 IST; Surface temperature: 303.6 K; Surface vapor density: 23.5 g/m^3.
B: Date: 15.07.1991; Time: 05:00 IST; Surface temperature: 300 K; Surface vapor density: 22.3 g/m^3.
C: Date: 17.01.1991; Time: 05:00 IST; Surface temperature: 287 K; Surface vapor density: 10.81 g/m^3.
D: Date: 17.01.1991; Time: 17:00 IST; Surface temperature: 293.7 K; Surface vapor density: 7.61 g/m^3.

Table 1. The variation of the peak and window frequencies with variable liquid-water content.

It is revealed from these analyses that in the monsoon months, the suitable frequencies on either side of the resonance peak are 21.367 or 23.055 GHz. But, on the other hand, during the winter season, the frequencies are 20.704 and 23.710 GHz. Hence, either of the frequencies cited above may be used, in addition to the window frequencies, for monitoring water vapor and liquid water.

3. Discussion

It has been assumed that the dimensions of water drops are much less than the wavelength of the incoming signal. Here, in the present context, it has been assumed that liquid water exists only when the relative humidity exceeds a certain value. It has also been assumed that the lower limit for relative humidity within a typical type of cloud is 95%, with water particles having a diameter range of 10-50 micrometers. However, for remote-sensing purposes, it is always suggested that the window frequency suitable for a particular place of choice be selected, which, in turn, depends on the liquid-water content over a particular location.

4. Conclusion

It is clear from Table 1 that with more liquid-water content, the shifting of the window frequency towards the left is large. Thus, for a high content of liquid water, the possible choice of window frequency may lie within the range of 25-28 GHz, instead of the conventional 31.4 GHz as suggested by Westwater [15]. However, proper care has

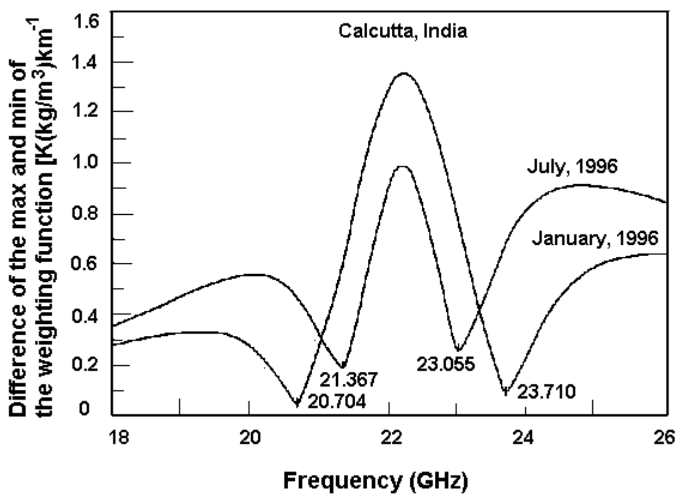

Figure 6. The difference of the maximum and minimum values of the water-vapor weighting function [K(g/m^3)km^{-1}] as a function of frequency.

to be taken if one wishes to select the resonant frequency in addition to the window frequency. Again, referring back to Table 1, it may be suggested that the frequency peak occurring at around 22.4-22.6 GHz for varying meteorological conditions may be deployed. However, it may also be noted that the use of dual-frequency radiometry, exploiting 22.235 and 31.4 GHz for the estimation of water vapor content, reduces the rms error to 2%, from 5% obtained by using only 22.235 GHz [14].

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Radio-Frequency Radiation Safety and Health

James C. Lin

The Auditory Perception and Hearing of Microwaves

In common usage, the handset of a wireless telephone is held against the ear. Computational and experimental studies have demonstrated that about 50% of the radiated radio frequency (RF)/microwave energy is deposited in tissues on the same side of the head, nearest to the telephone. The deposited energy, measured as specific absorption rates (SAR) of RF/microwave energy, is non-uniformly distributed inside the head. Depending on the specific model used, the SAR inside the inner ear is about 20% to 40% of that permissible by existing rules and regulations.

The permissible SAR from exposure to cellular mobile telephone radiation in Europe, Japan, and by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) is 2 W/kg in any 10 g of tissue in the head. The maximum SAR allowed by rules of the US Federal Communication Commission (FCC) and IEEE standards is 1.6 W/kg in 1 g of tissue.

The possible health risks associated with mobile telecommunication devices used close to the human head – and, in particular, the effects on the inner ear and hearing of users – have been recommended for further investigation by several groups. Recently, a number of projects have been initiated in France, Germany, and Italy to investigate the structures and functions of the middle and inner ear following exposure to wireless-communication radiation. Examination of the organic correlation of damage to hearing and any functional otoacoustic effects on the cochlear epithelium in the inner ear of rats, exposed to wireless-communication radiation, is still in the preliminary stage [1]. Thus, the potential effect on the auditory system, as may be revealed through objective evaluation of organic correlates, must await conclusion of the ongoing experiments. However, the phenomenon of microwave-induced auditory sensation in humans and animals is a well-established effect [2, 3].

The microwave auditory phenomenon, or microwave-hearing effect, pertains to the hearing by humans and laboratory animals of short pulses of modulated microwave radiation at high peak power. Anecdotal and journalistic reports of the hearing of microwave pulses persisted throughout the 1940s and 1950s. The first scientific report of the phenomenon appeared in 1961 [4]. The effect has been observed for RF exposures across a wide range of frequencies (450-3000 MHz). It can arise, for example, at an incident energy-density threshold of 400 mJ/m^2 for a single 10-microsecond-wide pulse of 2450 MHz microwave energy, incident on the head of a human subject. And, it has been shown to occur at a SAR threshold of 1.6 kW/kg for a single 10-microsecond-wide pulse of 2450 MHz microwave energy, impinging on the head. A single microwave pulse can be perceived as an acoustic click or knocking sound, and a train of microwave pulses to the head can be sensed as an audible tune, with a pitch corresponding to the pulse-repetition rate (a buzz or chirp). Note that the SAR threshold of 1.6 kW/kg is about 1000 times higher than that allowable by FCC rules for cellular mobile telephones.

The hearing of microwave pulses is a unique exception to the airborne or bone-conducted sound energy normally encountered in human auditory perception. The hearing apparatus responds to acoustic or sound pressure waves in the audible frequency range, but the hearing of microwave pulses involves electromagnetic waves, with frequencies ranging from hundreds of megahertz (MHz) to tens of gigahertz (GHz). Since electromagnetic waves (e.g., light) are seen but not heard, the report of auditory perception of microwave pulses was at once astonishing and intriguing. Moreover, it stood in sharp contrast to the responses associated with continuous-wave (CW) microwave radiation. Initially, it had been interpreted to imply direct microwave interaction with the neurophysiological system [4, 5].

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[Editor's note: This is an updated version of J. C. Lin, "Hearing Microwaves: The Microwave Auditory Phenomenon," *IEEE Antennas and Propagation Magazine*, **43**, 6, 2001, pp. 166-168.]

We now know that the microwave auditory phenomenon does not arise from an interaction of microwave pulses directly with the auditory nerves or neurons along the auditory neurophysiological pathway of the central nervous system. Instead, the microwave pulse, upon absorption by soft tissues in the head, launches a thermoelastic wave of acoustic pressure that travels by bone conduction to the inner ear. There, it activates the cochlear receptors, via the same process involved for normal hearing.

The microwave auditory effect is the most widely accepted biological effect of microwave radiation – aside from tissue heating – with a known mechanism of interaction: the thermoelastic theory of the microwave-induced acoustic pressure waves in the head. However, there is little data regarding effects on the inner-ear hearing apparatus or the central nervous tissue from exposure to these microwave pulses. It is clear that threshold microwave auditory response would have an insignificant effect on the hearing apparatus. However, any health effect that may attend exposure over a prolonged period, or exposure to supra-threshold microwave pulses, has not been investigated systematically.

In general, the mechanism of microwave interaction with biological systems is poorly understood. Studies on interaction mechanisms, although difficult, are important for gaining a better understanding of the biological phenomenon. They are invaluable in guiding future research, and they can support the development of safe exposure standards. As the thermoelastic theory of the microwave auditory effect illustrates, a genuine physical explanation of the effect is not only *descriptive* (capable of describing the biological phenomenon), it is *predictive* and *prescriptive*, as well. The predictive attribute provides a theory with parametric relations among its dependent variables that could be further studied, and the prescriptive feature delineates experiments that could be conducted to test its predictions.

The acceptance of the microwave-pulse-induced auditory effect was enhanced by two independent lines of experimental research: discrimination response in behavioral tests, and electrophysiological recordings, which have contributed to the definition of the characteristics, mechanism, and transduction of this phenomenon.

The fact that microwave pulses are acoustically perceptible and can serve as a discriminatory, auditory cue in behavioral tests was studied by several investigators. For example, food-deprived laboratory rats were trained to make a nose-poking response to obtain food only during presentation of an acoustic cue (7.5 kHz acoustic pulse, 3 μs wide, 10 pps). After the behavior was conditioned to the acoustic stimulus, 900 MHz microwave pulses (peak power density of 150 kW/m^2, 10 μs, 10 pps) were surreptitiously substituted for the acoustic stimulus. The animal demonstrated a continued ability to perform correctly (at 85%-90% level) on the discriminative task when presented with either the acoustic or the pulsed microwave cues.

Behavioral studies rely on inference, rather than direct measurement of the anatomical or physiological substrates involved in the microwave-pulse interaction with the auditory system. They should therefore be complemented by direct observations in identifying the anatomical and/or physiological evidence.

Such observations have been made through direct neurophysiological investigations in animals. On many sites along the auditory neural pathway, small electrodes may be inserted to record electrical potentials that arise in response to acoustic-pulse stimulation. If the electrical potentials elicited by a microwave pulse exhibited characteristics akin to those evoked by conventional acoustic pulses, this would vigorously support the behavioral findings that pulsed microwaves are acoustically perceptible. Furthermore, if microwave-evoked potentials were recorded from each of these loci, this would lend further support to the contention that the microwave auditory phenomenon is mediated at the periphery, as is the sensation of a conventional acoustic stimulus. Indeed, a large amount of accumulated electrophysiological evidence demonstrates that auditory responses are elicited by microwave pulses, and that these responses are similar to those evoked by conventional acoustic pulses. Evoked-potential recordings have been obtained from the vertex of the head, from the inner ear, and from the central auditory nervous system of cats, guinea pigs, and rats.

Specifically, responses recorded from the vertex represent volume-conducted electrical events that occur in the auditory brainstem nuclei within the first 8 ms after the onset of an acoustic stimulus. Comparable brainstem auditory-evoked responses have been recorded from cats, guinea pigs, and rats. Moreover, essentially identical microwave- and acoustic-pulse-evoked neural electrical activities were recorded from five levels of the central auditory system: the primary auditory cortex, medial genicular nucleus, inferior colliculus nucleus, lateral lemniscus nucleus, and the superior olivary nucleus. Thus, the same pathway through the central auditory nervous system is activated by both microwave and acoustic pulses. Also, the classical components of the action potential from the auditory branch of the eighth cranial nerve and the round window of the cochlea appeared in both microwave and acoustic pulse cases. These results suggest that the site of initial interaction of a pulse-modulated microwave radiation with the auditory system is at or outside the cochlea of the inner ear.

This interpretation is augmented by observations made in systematic studies of loci involved through production of coagulative lesions in ipsilateral auditory nuclei and bilateral ablation of the cochlea, the known first stage of transduction for acoustic energy into nerve impulses. Successive lesion production in the inferior colliculus, lateral lemniscus, and superior olivary nuclei resulted in a drastic reduction of the recorded response amplitude. The consequence of cochlear disablement was abolishment of all potentials recorded from three levels of the auditory nervous system (the primary auditory cortex, the brainstem nucleus, and the eighth nerve), evoked by both microwave and acoustic pulses. These data indicate that the peripheral site of initial interaction of pulse-modulated microwave radiation with the auditory system is, indeed, distal to the cochlea of the inner ear.

A peripheral interaction should involve displacement of tissues in the head, with resultant dynamic effects in the cochlear fluids, hair cells, and nervous system: consequences that have been well described for the acoustic case. In fact, the cochlear microphone response, a signature of mechanical disturbances in the cochlear hair cells, has been demonstrated in cats and guinea pigs subjected to microwave-pulse exposure. These results confirmed that the microwave auditory effect is mediated by a physical transduction mechanism, initiated outside the inner ear, and involves mechanical displacement of biological tissues.

Among the several transduction mechanisms suggested that involve mechanical displacement, thermoelastic expansion has emerged as the most effective mechanism. The pressure waves generated by thermoelastic stress in brain tissue are found to be one to three orders of magnitude greater than any other candidate mechanism. A detailed mathematical analysis has shown that the minuscule (10^{-6} °C) but rapid rise in temperature in the head of animals and humans as a result of the absorption of pulsed microwave energy creates a thermoelastic expansion of tissue matter, which then launches an acoustic wave of pressure that travels to the cochlea, and is detected by the hair cells there.

The thermoelastic theory of auditory perception of pulsed microwaves describes the acoustic waves (frequency, pressure, and displacement) generated in the head as functions of head size, and the characteristics of impinging and absorbed microwave energies. In addition to the expected dependence of sound pressure on the intensity of microwave pulses, it prescribes the dependence of induced sound pressure (perceived loudness) on pulse width, and the dependence of induced sound frequency on head size. For example, the theory predicts a fundamental sound frequency that varies inversely with head radius: the smaller the radius, the higher the frequency. For a rat-size head, it predicts a sound frequency of 25 to 35 kHz, which a rat could detect. For the size of a human head, the theory predicts frequencies between 7 and 15 kHz, which is within the range audible by humans.

It is significant to note that physical measurements, using a hydrophone (3 mm in diameter) implanted in the brains of cats, rats, and guinea pigs, and in brain-equivalent spherical head models, showed sound frequencies as predicted by the theory. Moreover, pressure waves propagating at a speed of 1523 m/s were observed in the brains of cats irradiated with pulsed microwaves.

Experiments performed using human and animal subjects and theoretical predictions have shown that the sound pressures initially increase with pulse width, but soon reach a peak, and then oscillate gradually to a lower value with further increases in pulse width. A study of loudness-perception variation with pulse width on human subjects in Moscow [6] also lent support to the thermoelastic theory, since it showed similar characteristics. The study had been designed to disprove the thermoelastic theory [7, 8], and yet, in the end, supported it [2].

The thermoelastic theory for hearing microwave pulses was developed on the basis of bulk absorption of pulsed microwave energy in the brain, which was assumed to be spherical for analytically clarity and simplicity [7, 8]. Recently, a numerical analysis was presented using the Finite-Difference/Time-Domain computational formulation, which is capable of detailed anatomic modeling of the brain and head structure [9]. Aside from confirming the characteristics of the induced acoustic waves, such as sound frequency and pressure amplitude, previously obtained using a homogeneous spherical head, the numerical computation graphically illustrated the sequence of pressure-wave propagation inside the head, following absorption of pulsed microwave energy. The pressure wave reverberated, and then focused near the center of the head.

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XXVIIth General Assembly

BUSINESS TRANSACTED BY COMMISSION B

Chair: Prof. Staffan Ström (Sweden)
Vice-Chair: Prof. Makoto Ando (Japan)

I. Report on the Open Commission Business Meetings

The Commission held three Open Commission meetings, respectively on 19, 21 and 23 August 2002. The Commission B Chair Prof. Staffan Strom opened the meeting and welcome all members who are interested in and supporting Commission B activities. They were attended by more than 50 delegates and members.

Schedule:
Business meeting I: 18:00-19:00, 19 August
Business meeting II: 18:00-19:00, 21 August
Business meeting III: 18:15-20:00, 23 August

I.1 Completion of the vote concerning Commission B incoming vice-chair

An important point on the agenda was the completion of the vote concerning incoming vice-chair. At the first business meeting, any Official Member who was present and had previously voted was given the opportunity to change his vote, and any Member who had not voted was allowed to do so. The result was that Prof. Lotfollah Shafai was elected, with Prof. Roberto Tiberio as alternate. (the URSI Council subsequently appointed Prof. Makoto Ando and Prof. Shafai as Commission B chair and vice-chair respectively, for the triennium 2002-2005).

I.2 Discussion of a proceedings in GA, a proposal to merge RRS and RSB and RSB on the web.

Dr. W. Ross Stone, URSI publication committee chair, explained the publication-related questions.

- How have CD-ROM proceedings and program with 100 words abstracts been received ?
  The changes were substantially supported with the exception of incomplete linkage to authors and the too small font-size for abstracts.
- Should the Review of Radio Science be incorporated into the Radio Science Bulletin?
  Generally supported especially in view of wider distributions and indexed in INSREC, more timely reviews and enhances RSB. The contents must be review articles so that they may compete with Radio Science.
- Should the Radio science Bulletin be made on the Web? Various advantages are discussed such as availability of back-numbers, wider distribution, reduction of printing and mailing cost and also enhancing the number of URSI correspondences.

I.3 Discussion of a proposed new format for Abstracts of papers submitted to the next GA: 4 pages

In 2002 GA, text only abstracts were submitted for review and the final version of the manuscript with the maximum of 4 pages +100 word abstract was requested for each accepted paper. The proposal of the new format for submission in the next 2005 GA, where a 4-page manuscripts are submitted once for both review and the proceedings, received substantial support.

I.4 Commission B Editor for RRS/RRB 2002-2005

Prof. R. Ziolkowski of the University of Arizona was appointed as Commission B Editor for RRS/RRB 2002-2005. (Dr. Ross Stone emphasized that the Commission Editors should select reiew topics and authors ASAP).

Each Commission has been asked to appoint a Commission Editor for the Review of Radio Science and the Radio Science Bulletin. Prof. R. Ziolkowski of the University of Arizona was charged with the Commission Editor for RRS/RSB 2002-2005. He accepted. The Commission should select review topics and authors with him in due course.

I.5 Special Section in Radio Science based on papers presented at the 2001 Victoria EMT.

Prof. A. Ishimaru reported on the current status of the editing of this Special Section in Radio Science. Prof. A. Ishimaru of Washington University is Co-Editor, together with the and Prof. S. Strom of Royal Institute of Technology, for this Special Section. Twenty one papers had been accepted and six more are under revision. The Special Section will appear in the 2002 Nov.-Dec. issue of Radio Science.

Radio Science has a special issue devoted to selected papers presented at the 2001 Electromagnetic Theory Symposium in Victoria. It is edited by Prof. Akira Ishimaru of the Washington University and Prof. Staffan Strom of the Royal Institute of Technology. The current status of the editing of the issue was explained. Twenty one papers were accepted and six more are under revision. This will appear in Nov.-Dec. issue of Radio Science.

I.6 Announcement of URSI Commission B Electromagnetic Prize

The present status of the Electromagnetic Prize with the first problem appearing on the web on September 15, 2001 and with the deadline of 15 January, 2003 was announced.

The second problem will be announced soon. During the next triennium after this GA, the panel that will evaluate the entries consists of Prof. Tom Senior, Dr Carl Baum, Prof Chalmers Butler, Prof. Karl Langenberg, and the Commission B (Past) Chair Staffan Strom.

I.7 Inter-Commission Working Group (IWG) on Solar Power Satellites (SPS)

Formation of IWG was proposed by Commission H. Microwave power transmission from space to earth is a challenging technology for Commission B and active participation as the commission is adopted. Dr. W. Ross Stone, Prof. Y. Rahmat Samii of UCLA, USA and Dr. Andrew J. Parfitt of CSIRO, Australia had applied upon the solicitation and their names were transmitted to the Commission H.

I.8 Presentation of the Italian proposal to host the future EMTS

Prof. G. Manara of University Pisa made a presentation of a proposal to hold the 2007 URSI Electromagnetic Theory Symposium (EMTS) in Pisa, Italy. The symposium could take place at the Congress Centre of the University of Pisa. Additional information on the proposal can be found at the following web address: www.ing.unipi.it/MRL/URSI.

The Chair, Prof. S. Strom, added that Commission B had received only one proposal for 2007 EMT-S and that the proposal had been reviewed and recommended by the Commission B ad hoc committee for EMTS proposals. After some questions and discussions, the Italian proposal was accepted by Commission B.

Prof. G. Manara of the University of Pisa made a presentation for proposal to hold the 2007 URSI Electromagnetic Theory Symposium (EMTS) in Pisa, Italy. The Symposium could take place at the Congress Centre of the University of Pisa. Additional information on the proposal can be found at the following web address: http://www.ing.unipi.it/MRL/URSI .

The Chair, Prof. S. Strom, added that Commission B received only one proposal for 2007 EMT-S and that the proposal had been reviewed and qualified by Commission B ad hoc committee. After some questions and discussions, Italian proposal was accepted by Commission B with the time of the symposium unspecified in view of the next agenda.

I.9 Discussion of related questions concerning 2004 and 2007 EMTS

The Chair, Prof. S. Strom, first explained that the upcoming 2004 EMTS was projected to bring about a break in a trend of somewhat decreased participation in EMTS series. He mentioned that the Commission B Chair and Vice-chair had discussed and assessed with Prof. S.E. El-Khamy, Chair of the local organizing committee of 2004 EMTS in Alexandria, the apprehension expressed by many members of the Commission B community concerning the latest political situation in neighbouring Middle East areas.They also were in contact with Prof. G. Manara and his colleagues, who were behind the italian proposal concerning the 2007 EMTS.

With this background, the following was proposed by the Commission B Chair: The venues/organizers of the 2004 and the 2007 EMTS are switched, so that instead of Alexandria in 2004 and Pisa in 2007, the 2004 EMTS will take place in Pisa in the last week of May (tentative) and the 2007 EMTS will take place in Alexandria. The proposal was approved unanimously by the meeting.

Furthermore, Commission B resolved unanimously to thank the Egyptian and Italian delegates for their gracious and constructive collaboration in reaching the above-mentioned consensus decision. Finally, the Chair brought the very tight schedule of less than two years for the preparation of 2004 EMTS in Pisa to the attention.

I.10 Best young scientist paper (BYSP) award

The chair announced that Dr.Maurizio Bozzi of the University of Pavia who was a YSA recipient and a member of the Commission B community, had won the Philips' best young scientist paper (BYSP) award. The meeting congratulated Dr. Bozzi to his award.

I.11 Vote of Thanks

Prof. Staffan Strom introduces the incoming chair, Prof. Makoto Ando, Japan. On behalf of the Commission B members, he warmly proposed a vote of thanks to the outgoing Chair, Prof. Strom, for the excellent way in which he had led the Commission during the last triennium. This was carried by acclamation.

I.12 The Commission B Technical Advisory Board (B-TAB)

The incoming Chair, Prof. Ando, explained the mission and role of Commission B Technical Advisory Board (B-TAB), which is a follow-up of the discussion that started at the 2001 EMTS in Victoria, Canada. The role of TAB is to discuss the future directions of study topics of Commission B and take the necessary action for realizing it. TAB investigate,

- Long-term directions of technical program. Advice and support to Technical Program Committees (TPC) of EMT-Symposia and GA.

- Possible cooperation with other Commissions and Societies. (SIAM was suggested in Victoria)
- How to attract and motivate young engineers or students in electromagnetics and/or related fields.

The current member list as well as the action time-table was announced. All the Commission members are solicited to support B-TAB discussion.

I.13 Any other business and announces during GA

The following topics were discussed or announced in other meetings such as Openinng Ceremony, Coordinating Committee and Council during GA.

Issac Koga Gold Medal

In the opening ceremony of the GA, the Issac Koga Gold Medal for this triennial was awarded to Prof. Frank Olyslager of University Ghent, who is the active young scientist in the field of Commission B.

Update of the terms of reference

It was not felt necessary to modify them.

Scientific Committee for Telecommunications (SCT)

The Council agreed the resolution on SCT. The resolution as well as the terms of reference are available on the URSI Website. SCT is reactivated to encourage the exchange of information between URSI and ITU. It is chaired by Mr. M. Hall and the membership tentatively comprises representatives of 10 Scientific Commissions and Participants. Anybody who wish to contribute to the "SCT discussion" is solicited to contact with Mr. M. Hall at <Martine.Hall@rl.ac.UK>. Commission B is also requested to coopt the individuals with any involvement in ITU-R, ITU-T, ITU-D and WHO.

Communications

During the triennium the Chair has communicated with the Commission B representatives through a series of e-mail " Letter no X ". All these letters and annexes can be viewed on the URSI Homepage at http://www.ursi.org/Maastricht/Comreportstri.htm. (tick Commission B)

Commission B will create a web page which is still under development and which contains information at this stage devoted primarily to the 2004 Electromagnetic Theory Symposium.

II. COMMISSION B PROGRAM IN MAASTRICHT GA

II.1 2002 Maastricht GA Commission B Sessions (Number of submitted papers)

A) BT. Tutorial: 1 hour

- Inverse Scattering and Its Applications to Sub-Surface Sensing and Medical Imaging: M. Van Den berg, Convener: Staffan Strom (Chair B)

B) Sessions organised by Commission B alone

- B1. Electromagnetic Theory (I&C&P) : 2 hours (46)
  Convenors: I.V. Lindell and P.D. Smith
- B2: Scattering and Diffraction (I&C&P) : 3 h. 20 min. (38)
  Convenors: Karl J. Langenberg and Marc Saillard
- B3 Time Domain Electromagnetics (I&C&P) : 3 h. 20 min. (27)
  Convenors: E.Miller and R. Gomez-Martin
- B4 Inverse scattering and imaging (I&C&P) : 3 h. 20 min. (25)
  Convenors: G. Kristensson and T. Habashy.
- B5 Fast Methods for CEM (I&C&P) : 2 h. 20 min. (10)
  Convenors E. Michielssen and J. Volakis
- B6 Numerical methods for PDEs - Adaptive feedback processes and multigrid techniques: 2 h. 20 min. (9)
  Convenors: J-F Lee and M. Salazar-Palma
- B7 Asymptotic and hybrid methods (I&C&P) : 2 h. 20 min. (16)
  Conveners: P. Pathak and G. Manara
- B8 Design, Analysis and Synthesis of Antenna Arrays (I&C&P) : 3 h. 20 min. (32)
  Conveners: S. Maci and T.S. Bird
- BP Electromagnetic waves in complex environments (39)
  Convenors: N. Engheta and E. Heyman

C) Joint sessions led by Commission B

- BCF Antennas in mobile communication systems (I&C&P) : 2 h. 20 min. (25)
  Convenors: M. Ando and G. Frolund Pedersen
- BD Time and frequency 3D circuit modelling (I&C&P) : 2 hours (10)
  Convenors: F. Olyslager and A. Cangellaris

D) Joint sessions led by other Commissions

- AB1: Antenna and Electromagnetic Field Measurements (I&C) (25)
  Convenors: T. Schrader and A. Yaghjian
- AB2: Time-Domain Measurements and Analysis (I&C) (4)
  Convenors: H Garbe and Anton G. Tijhuis
- CBF: Wave Propagation Modeling for Mobile Communication Systems (I) (15)
  Convenors: W.Wiesbeck and H. Bertoni
- CFAB Subsurface Remote Sensing with its Applications (11)
  Convenors: D. Noon, G. Smith, and P.v.d. Berg
- DB Electromagnetic Band Gap Structures and Their Applications (11)
  Convenors. R. Ziolkowski and Y Rahmat Samii
- JBC: Wideband Array Technology and Systems (I) (16)
  Convenors:A. van Ardenne G. L. James and H. Boelcskei
- KB: Computation of Electromagnetic Fields in the Human Body (I, C, P) (14)
  Convenors: O. Gandhi and M. Okoniewski

Session	Oral	Invited	Poster	No show	Participant (Approx.)	Submission
B-Tut.		*1*	*0*	*0*	*>200*	*1*
B1	*6*	*5*	*37*	*0*	*>100*	*46*
B2	*10*	*9*	*22*	*0*	*40*	*38*
B3	*11*	*11*	*9*	*0*	*40*	*27*
B4	*10*	*4*	*14*	*1*	*45*	*25*
B5	*6*	*5*	*3*	*0*	*70*	*10*
B6	*6*	*5*	*1*		*40-50*	*9*
B7	*7*	*5*	*9*		*50*	*16*
B8	*10*	*10*	*22*	*1*	*50*	*32*
BCF	*5D*	*2*	*20*	*1*	*48*	*25*
BD	*6*	*4*	*4*	*1*	*30*	*10*
BP	*5*	*34*				*39*
Total	*77*	***67***	***175***			***277***

BUSINESS TRANSACTED BY COMMISSION D

Chair: Professor A. Seeds (United Kingdom)
Vice-Chair: Professor P. Russer (Germany)

The Commission held two business meetings on 19 and 21 August 2002. This is a report on the main business transacted as well as on the Scientific Programme organised at the XXVIIth General Assembly of URSI.

I. Chair's report (Prof. Alwyn Seeds)

The last triennium has been active and successful. The commission focused financial support on international meetings of high scientific value (ISSSE01, AP-RASC01) and also supported six other meetings with publicity and technical informationship.

The balance of the commission budget in the amount of € 9,000 was used to support the registration fees for the general lecturer and a geographically spread group of invited speakers at the XVIIth General Assembly. The closing balance of € 75 should be carried forward by the incoming chairman.

A detailed report on the triennium is on the URSI Website.

II. New Chair and Vice Chair for '02-'05.

At the conclusion of the General Assembly, Professor Peter Russer, former Vice Chair, took over the Chair from Professor Alwyn Seeds. Two candidates had been nominated for the position of Vice-Chair of Commission D for 2002 to 2005, namely: Dr. Frédérique de Fornel (France) and Dr. Hiroyo Ogawa, Japan.

According to the URSI rules any official member who was present at the business meeting was given the opportunity to change his vote (if previously cast by mail). The votes cast for the Vice Chair candidates were: Dr. Frédérique de Fornel (21) and Dr. Hiroyo Ogawa (21).

Since either candidates won equal numbers of votes, Commission D recommended to the Council to choose one of the candidates under consideration of the international balance of the chairs. Subsequently, Dr. de Fornel was appointed by the Council Vice Chairman of the Commission D for the triennium 2002-2005.

III. Appointment of Commission D Editor for Review of Radio Science

The Vice-Chair will be appointed editor of RRS. Both candidates for Vice Chair had indicated that they would undertake this task, if elected.

IV. Radioscience Bulletin. Appointment of Comm. D Associate Editor

The commission editor will be Smail Tedjini, replacing Roberto Sorrentino who completed his three-year term in this post.

V. Evaluation of Young Scientist program

The Commission D decided to grant the Young Scientist Award to Ondrej Cip, Josef Lazar and Frantisek Petru for their contribution "*Frequency Method of Sub-Nanometer Distance Measurement*".

The paper has been considered extremely clearly written. The results are truly state of the art. This work solved an actual scientific and engineering problem excellently.

VI. Terms of Reference

Since electronic and photonic devices have reached system level, the commission noted that this development has to be considered in the terms of reference. Changes in the first two terms of reference were suggested: The first term of reference *"Electronic devices and applications"* should be changed to *"Electronic devices, circuits and applications" and* the second term of reference *"Photonic devices and applications"* should be changed to *"Photonic devices, systems and applications"*. It was resolved unanimously to change the terms of reference in the proposed way. In the Council meeting the wider extension of the terms of reference into "*Electronic devices, circuits, systems and applications (a) Photonic devices, systems and applications (b) Physics, materials, CAD, technology and reliability of electronic and photonic devices, with particular reference to radio science and telecommunications"* was been discussed and approved.

The Commission deals with devices for generation, detection, storage and processing of electromagnetic signals together with their applications, covering all frequencies, including those in the microwave and optical domains.

VII. Proposed nominations for URSI Committees

A Committee on Extraterrestrial Solar Power Generation is proposed. Prof. Tatsuo Itoh should represent Commission D in this Committee. Professor Itoh has indicated that he would undertake this task.

VIII. International Symposium on Signals, Systems and Electronics

Professor Robert Weigel from the University Erlangen-Nürnberg offered to organize the 2004 International Symposium on Signals, Systems, and Electronics (ISSSE'04) in Austria. As conference venue he proposed either Linz (Johannes Kepler University) or Salzburg (Congress Center). The conference duration will be three days. Three parallel Sessions are planned. Both cities have very good accessibility by train and by car. Due to the University infrastructure the conference costs in Linz would be much lower than in Salzburg. The attendees had some preference to Linz but decided to agree with either venue options.

IX. Scientific Program of Next General Assembly

The Commission discussed possible topics for the Scientific Program of the next General Assembly. Professor Russer reminded attendees that they should respond to the form "Commission D Suggested Topics for 1999 GA". This form should be sent to Professor Russer (russer@ei.tum.de).

Suggestions should start now and may be made up to 18 months before the next GA. Suggestions made at the business meeting were 10) Wide band gap materials (diamond, SiC) for devices at microwave frequencies, 11) Micromachined millimeterwave devices, 12) Spin state electronics, 13).Tutorial on so-called electromagnetic band gap structures.

X. Scientific Program at XXVII URSI General Assembly

The Commission organised seven technical sessions, and co-organised ten additional sessions in cooperation with other Commissions or other Organisations, such as ICO and IWGP. In three of such sessions Commission D was the principal Organiser.

Most of the sessions were very well attended, particularly those covering topics of broad interest, such as MMIC's, wide band gap devices, etc. A few of them were focused on specialized topics, in which case the attendance was somewhat less.

X.1 Summary of the technical sessions held during the XXVII General Assembly

Session D1: Radio over Fiber Technologies

Chairpersons: T. Berceli (Hungary) and H. Ogawa (Japan)

In recent years optical fiber links have gained wider applications in mobile communications, local area and subscriber access networks, television programme distribution, etc. In most cases the optical link is combined with wireless connections. The radio over fiber approach allows for optical transmission of information channels transposed on radio frequency carriers simplifying this wave the optical/wireless interfaces. The session gave a survey on the new device, circuit and system technologies for the radio over fiber approach.

Session D2: Femtosecond Terahertz Technology

Chairpersons: Hiromas ITO (Japan) and Osamu WADA (Japan)

The objective of this session was to examine techniques for the generation, processing and detection of ultra-fast signals in both the time and frequency domains. The topics included quantum well excitons, THz-wave parametric generators, stimulated emission in the THz region and superradiant semiconductor heterolasers.

Session D3: Optical-Microwave Interactions.

Chairperson: Le Nguyen Binh (Australia)

Interactions between microwaves and optical waves find application in spectrum analysis of RF signals, guided waves in photonic crystal structures and detection of microwave fields by optical radiation. The topics included photonic spectrum analysis of wideband rf pulsed signals, photonic crystal optical waveguides, so-called photonic band gap structures, and microwave detection in semiconductor structures by optical radiation.

Session D4: Nanotechnologic Processes for Advanced Optic and Electronic Systems

Chairpersons: Pierre-Noël Favennec (France) and Frédérique de Fornel (France)

Nanotechnology processes allow the realisation of new electronic and optical devices and systems; they also allow goal-improved performances for more classical devices. Specific topics included: atomic or molecular deposition, semiconductor microcrystallites in various matrixes, nanolithography, nanoscale processes, nanomanipulation, molecular engineering, nanostructure characterization, novel electronic devices and nanosensors.

Session D5: Wave Propagation in Fast Photonic Devices

Chairperson: Le Nguyen Binh (Australia)

Electro-optic devices are essential for ultra-high speed optical modulation of light waves in optical communications and photonic signal processing systems. Topics included the design and implementation of travelling wave electrodes, noise of mode-locked lasers, electrooptic Mach-Zehnder waveguide modulator design, and electrooptic travelling-wave modulator simulation.

Session D6: MEMS (Microelectromechanical Systems) in Microwaves, Millimeterwaves and Optics

Chairperson: Peter Russer (Germany)

Microelectromechanical systems allow switching and other operations in fast electronic systems to be carried out with remarkably reduced size and circuit parasitics relative to conventional techniques. Ingenious applications in low loss compact optical switching have also been shown to be possible. This session addressed both the technology and the applications of these devices. Topics included rf MEMS switches and high-Q elements, distributed rf-MEMS circuits, electromagnetic modelling of rf MEMS structures and future nanoscale MEMS devices.

Session D7: Photonic Signal Processing

Chairperson: Le Nguyen Binh (Australia)

Processing of signals at extremely high radio frequency up to and beyond several hundred GHz is critical for ultra-high speed optical communications and defence systems. Generation, detection, filtering and regeneration of these signals in the time and optical frequency domain by in-line optical guided systems were treated in this session.

Session DP: Open Contributed Poster Session

M. Pyée (France)

This session was open to papers in all aspects of electronics and microelectronics materials or components not covered by the other sessions as well as to new results.

Session DB: Electromagnetic Band Gap Structures and their Applications

Chairpersons: R W. Ziolkowski (D, USA) and Yahya Rahmat-Samii (B, USA)

Electromagnetic band gap (EBG) structures are finite/infinite periodic 1D/2D/3D arrangements of electric or magnetic materials, which produce a band gap in either the temporal or spatial frequency response of that structure. Contributions to this session included transmission lines, filters, coupled cavities and antennas on periodic band-gap structures.

Session DJ: Photonics in Radio Astronomy

Chairpersons: C. H. Cox (D, USA) and J.M. Payne (J, USA)

Photonics is increasingly being used to perform a variety of roles in radio astronomy instruments. Originally considered only hypothetically as a technology for remoting the antenna signals, photonics has recently moved to the enabling technology for several radio astronomy telescopes. Speakers who are actively engaged in the challenge of implementing these new or upgraded telescopes have contributed to this session, discussing the options they considered, the tradeoffs of the various photonic approaches and the approach they have implemented.

Session DJA: Advances in Superconductor Components and Applications

M. Pyée (D, France) and G. Beaudin (J, France)

This session focused on the advancement of the superconductor components as well as on applications. The following topics were covered: Advances in the new high Tc superconductor materials for electronics applications, RSFQ logic circuits, Advances in magnetic fields measurements using SQUIDs, applications in metrology, microwave circuits and receivers for radio-astronomy.

D-Tutorial: Ultra-Fast Photonic Networks based on Optical Code-Division Multiplexing

Hideyuki Sotobayashi (Japan)

Professor H. Sotobayashi (Japan) presented an excellent introduction and overview on Photonic Networks based on Optical Code-Division Multiplexing.

BUSINESS TRANSACTED BY COMMISSION F

Chair: Dr. Yoji Furuhama (Japan)
Vice-Chair: Prof. Martti Hallikainen (Finland)

The Commission held three Open Business Meetings, respectively, on 19, 21, and 23 August 2002. Copies of the agenda and of the Commission F report to Council for 1999-2002 (published in the September 2002 issue of the Radio Science Bulletin) were made available to attendees. The following items were discussed at the meetings.

I. Election of Vice-Chair

Member Committee Representatives had had the opportunity to vote for Vice-Chair by mail, with the candidates being Dr. Gabriel Ajayi (Nigeria), Prof. Piotr Sobieski (Belgium) and Dr. Ed Westwater (USA). As the Council had in its meeting on 18 August decided to expel Nigeria from URSI due to unpaid membership dues, Dr. Ajayi was removed from the list of candidates and Representatives were given the opportunity to vote for the two remaining candidates by marking two points for the first choice and one point for the second choice. Credentials of those voting were checked.

Based on the election outcome, the following names were proposed to the Council, in order of preference:
1. Piotr Sobieski (Belgium)
2. Ed Westwater (USA)

The Commission confirmed its wish that Prof. Martti Hallikainen would become Chairman at the conclusion of the General Assembly. {The Council subsequently confirmed the appointment of Prof. Piotr Sobieski.}

II. 2002 General Assembly Programme

II.1 Commission F Sessions

Commission F organised nine scientific oral sessions of invited papers and a large poster session. The Session titles and convenors were as follows:
- F1: Radiometeorology, Rod Olsen (Canada) and J. Pedro Poiares Baptista (The Netherlands)
- F2: Climate parameters in radiowave propagation and their modelling, Terje Tjelta (Norway) and Carlo Riva (Italy)
- F3: Millimetric, Sub-millimetric and optical wave propagation prediction, Chris Gibbins (UK) and Takeshi Manabe (Japan)
- F4: Point to point and point to multipoint propagation, Joel Lemorton (France) and Marlene Sabino Pontes (Brazil)
- F5: Microwave passive remote sensing, Ed Westwater (USA) and Adriano Camps (Spain)
- F6: Microwave active remote sensing, Paolo Pampaloni (Italy) and Jouni Pulliainen (Finland)
- F7: Polarimetric and interferometric techniques in remote sensing, Shane Cloude (UK) and Alberto Moreira (Germany)
- F8: Active microwave remote sensing of ocean, Yoji Furuhama (Japan) and Martti Hallikainen (Finland)
- F9: Passive remote sensing of atmosphere, Haruhisa Simoda (Japan) and Thuy Le Toan (France)
- FP: Wave propagation and remote sensing, Martti Hallikainen (poster session).

Dr. Furuhama asked session convenors to provide a one-paragraph description to Prof. Hallikainen after their sessions for use in the report to be published in Radio Science Bulletin (RSB).

Ten sessions were organized jointly with other Commissions. The joint sessions (the first letter points out the lead Commission) and their convenors were:
- FG: Wave propagation for satellite navigation and mobile services, Bertram Arbesser-Rastburg (F, The Netherlands) and David Rogers (F, Canada)
- BCF: Antennas in mobile communication systems, Makoto Ando (B, Japan) and Gert Frølund Pedersen (C, Denmark)
- CAF: Broadband access systems in wireless communication, H. Ogawa (Japan) and Torbjörn Tanem (Norway)
- CBF: Wave Propagation modeling for mobile communication systems, Werner Wiesbeck (Germany) and Henry Bertoni (USA)
- CF: Adaption to changing radio channel, Robert Bultitude (C, Canada) and Yashio Karasawa (F, Japan)
- CFA: Channel sounding in mobile communication systems, Reiner Thoma (C, Germany) and Simon Saunders (F, UK)
- CFAB: Subsurface remote sensing and its applications, Jürgen Sachs (C, Germany) and David Noon (F, Australia)
- EF: Interference in communication, Jacob Gavan (E, Israel) and David Bacon (F, United Kingdom)
- GF: Transionospheric signal degradation, Reinhart Leitinger (G, Austria) and Manuel Cervera (G, Australia)
- JCF: Interference mitigation in radio science, Michael Kesteven (J, Australia) and Wolfgang-Martin Boerner (F, USA).

Sessions FG and GF were originally planned as Commission F and G regular sessions, respectively. In the Coordinating Committee meeting in April 2001 it was decided to organise them as joint sessions due to mutual interest.

Each session convenor was provided with a copy of the questionnaire prepared by Mr. Martin Hall, GA Scientific Programme Coordinator. Convenors were asked to fill in the questionnaire immediately after their sessions and return them to Mr. Hall with a copy to Prof. Hallikainen.

Commission F sessions were felt to be technically and geographically well balanced, but they could have involved more young scientists. (See 5.1.)

II.2 Commission F Tutorial

The intended tutorial was replaced at short notice with the following presentation: "Shane Cloude (UK): *Recent developments of data processing in polarimetric and interferometric SAR*."

II.3 Commission F Contribution to Review of Radio Science (RRS) 1999-2002

The Commission F chapters in the URSI Review of Radio Science 1999-2002 are:

- Adriano Camps (Spain) and Calvin Swift (USA): New techniques in microwave radiometry for Earth remote sensing (Chapter 22)
- Arnold Dekker (Australia) and Robert Bukata (Canada); Remote sensing of inland and coastal waters (Chapter 23)
- David Noon (Australia) and Ram Narayanan (USA): Subsurface remote sensing (Chapter 24)
- Bertram Arbesser-Rastburg (The Netherlands) and David Rogers (Canada): Wave propagation for multimedia satellite services (Chapter 25).

Prof. Hallikainen was to be Commission F Editor for RRS. Dr. Furuhama expressed his thanks to all those having contributed to Commission F presentations and contributions to RRS.

II.4 Philips' Young Scientist Paper Award

Dr. Furuhama announced that Commission F had an opportunity to nominate a candidate for the special Philips' Young Scientist Paper Award; he showed the list of eight Commission F Young Scientist Programme awardees. The task was entrusted to Dr. Furuhama and he subsequently proposed Ms. Chieko Ito (Japan; paper no. 181) as the candidate of Commission F to the Philips' Award Committee.

III. Matters Relating to Council and the Coordinating Committee

III.1 Response to URSI Publications Committee's Proposals

Dr. Furuhama presented the report of URSI Publications Committee and its proposal to (a) combine the Review of Radio Science (RRS) with the Radio Science Bulletin (RSB) and (b) make it available on the Web (this would not eliminate the paper version). He also presented the reasoning for this proposal, including wider dissemination of RSB, more timely reviews and enhancing the technical content of RSB. Also back issues of RSB could be made available on the Web. Commission F recommended incorporation of RRS into RSB and making RSB available on the Web. Additionally, the new CD-ROM Proceedings and the 100-word abstracts were well received.

Prof. Piotr Sobieski was appointed as Commission F Editor for RSB/RRS. His responsibility is to select review topics and authors for reviews in the areas of interest to Commission F, or to set up a procedure to do so. {The Council subsequently approved the merger of the Review of Radio Science with the Radio Science Bulletin.} Commission F has to submit 2 to 3 review articles per year on relevant topics to be published in the Radio Science Bulletin.

III.2 Resolutions, Recommendations and Opinions

Dr. Furuhama said that information on URSI resolutions, recommendations and opinions was available on the Web.

III.3 Terms of Reference

An extensive discussion was conducted on Commission F Terms of Reference. It was generally felt that there was a need to modify them. A committee consisting of Dr. Yoji Furuhama, Dr. Thuy Le Toan, and Prof. Richard Moore was established, and they later presented a draft for the new Terms of Reference. {The Council subsequently confirmed the Terms of Reference in the following form: *"Commission F – Wave Propagation and Remote Sensing (planetary atmospheres, surfaces and subsurfaces)"*

The Commission encourages:

(a) The study at all frequencies in a non-ionised environment: (i) wave propagation through planetary neutral atmospheres and surfaces, (ii) wave interaction with planetary surfaces and subsurfaces including land, ocean and ice, (iii) characterization of the environment as it affects wave phenomena;

(b) The application of the results of these studies, particularly in the areas of remote sensing and communications;

(c) The appropriate co-operation with other URSI Commissions and other relevant organizations."

III.4 Relations between URSI and ITU

Mr. Hall briefly commented on relations between URSI and other application-oriented organisations, a topic that URSI Council considers to be important. He invited people to attend the open meeting of SCT (Scientific Committee on Telecommunications) to be organised during the General Assembly. (See also 9.)

IV. Inter-Assembly Meetings

IV.1 Commission F Meetings in Last Triennium

Commission F was sponsor or co-sponsor of 23 meetings between the 1999 and 2002 URSI General Assemblies. URSI can sponsor meetings in Mode A, B, or C (see URSI Home Page). Mode A meetings can explicitly use the name and logo of URSI, but no financial commitment is involved. URSI grants a fixed, unconditional sum to meetings under Mode B sponsorship, but the support is strictly restricted to cover expenses of Young Scientists, key speakers, or other scientists considered essential to the meeting (but not organisational costs). Awards to such individuals may be appropriate if normal funding from outside URSI is not available. Under sponsorship Mode C URSI grants to a meeting a sum that is to be regarded as a loan. This sum may typically be used to cover preparatory expenses. It may be combined with an additional, fixed unconditional sum to be used in accordance with Mode B. URSI should be involved in sharing any profits from the meeting under Mode C sponsorship.

The main Commission F meeting between URSI General Assemblies was the Commission F Triennial Open Symposium, held this time in Garmisch-Partenkirchen, Germany on February 11-15, 2002 (Mode B). The Commission F Specialist Meeting on Microwave Remote Sensing of the Earth, Oceans, Ice, and Atmosphere (Mode B) was held in Boulder, CO, USA on November 5-9, 2001. Climpara'01 was held in Budapest, Hungary on May 28-30, 2001 (Mode B); this was the fifth in a series of meetings which link closely with ITU-R Working Parties 3J and 3M.

Commission F, as usual, co-sponsored with the IEEE Geoscience and Remote Sensing Society three International Geoscience and Remote Sensing Symposia (IGARSS), all as Mode A. These are the largest annual remote sensing meetings and continue to draw about 1000 presentations. IGARSS 2000 was held in Honolulu, Hawaii, USA on July 24-28, 2000, IGARSS 2001 was held in Sydney, Australia on July 6-10, 2001, and IGARSS 2002 was held in Toronto, Canada on June 28 - July 2, 2002.

The locations, dates and Modes of the sponsored meetings are shown below. Available meeting Home Pages are indicated, although they may not be accessible in the future. Conference reports in the Radio Science Bulletin (RSB) are also indicated.

Mode A:

- Radio Africa'99: Third Regional Workshop on Radiocommunication in Africa, Gaborone, Botswana, October 25-29,1999 (RSB, September 2000, pp. 6-8)
- AP2000: Millennium Conference on Antennas & Propagation, Davos, Switzerland, April 9-14, 2000 (http://www.estec.esa.nl/AP2000/)
- EUSAR 2000: European Conference on Synthetic Aperture Radar, Munich, Germany, May 23-25, 2000 (http://www.fgan.de/fhr/eusar2002) (RSB, March 2001, p. 14)
- GPR 2000: Eighth International Conference on Ground Penetrating Radar, Gold Coast, Queensland, Australia, May 23-26, 2000 (http://www.cssip.uq.edu.au/gpr2000) (RSB, June 2001, p.19)
- 33rd COSPAR Scientific Assembly, Warsaw, Poland, July 213-26, 2000 (http://cospar.itodys.jussieu.fr) (RSB, June 2001, pp.20-22)
- IGARSS 2000: IEEE International Geoscience and Remote Sensing Symposium 2000, Honolulu, Hawaii, USA, July 24-28, 2000 (http://www.igarss.org)
- ISAP 2000: International Symposium on Antennas and Propagation, Fukuoka, Japan, August 22-25, 2000 (http://www.crl.go.jp/pub/ISAP2000)
- MMET 2000: International Conference on Mathematical Methods in Electromagnetic Theory, Kharkov, Ukraine, September 12-15, 2000 (http://www.kharkov.ukrtel.net/MMET2000)
- Antennas and Propagation for Wireless Communications, Waltham, MA, USA, November 6-8, 2000.
- EPMCC 2001: Fourth European Personal Mobile Communications Conference, Vienna, Austria, February 20-22, 2001 (http://www.epmcc.com)
- ICAP 2001: Eleventh International Conference on Antennas and Propagation, Manchester, UK, April 18-20, 2001 (http://www.iee.org.uk/Conf/ICAP)
- Remote Sensing for Monitoring the Baltic Sea and Other Interior Basins, Kaliningrad, Russia, May 14-17, 2001 (http://www.ire.rssi.ru)
- MSMW 2001: Fourth International Symposium on Physics and Engineering of Millimeter and Submillimeter Waves, Kharkov, Ukraine, June 4-9, 2001 (http://www.ire.kharkov.ua/MSMW2001/msmw.htm) (RSB, September 2001, pp. 19-21)
- IGARSS 2001: IEEE International Geoscience and Remote Sensing Symposium, Sydney, Australia, July 9-13, 2001 (http://www.IGARSS2001.org)
- ICEAA 2001: International Conference on Electromagnetics in Advanced Applications, Turin, Italy, September 10-14, 2001.
- AMEREM 2002: The American Electromagnetics 2002 Symposium, Annapolis, Maryland, USA, June 3-7, 2002 (http://www.amerem.org)
- EUSAR 2002, Cologne, Germany, June 4-6, 2002 (http://www.fgan.de/fhr/eusar2002)
- IGARSS 2002: IEEE International Geoscience and Remote Sensing Symposium, Toronto, Canada, June 24-28, 2002 (http://www.igars02.ca).

Mode B:

- MST9-COST76 Workshop (Ninth International Workshop on Technical and Scientific Aspects of MST Radar combined with the COST-76 Final Profiler Workshop), Toulouse, France, March 13-17, 2000 (156 participants from 27 countries) (http://www.cnrm.meteo.fr/mst/)
- Climpara'01 (Climatic Parameters in Radiowave Propagation Prediction), Budapest, Hungary, May 28 - 30, 2001 (http://www.climpara.org/)
- 2001Asia-Pacific Radio Science Conference (AP-RASC'01), Tokyo, Japan, August 1-4, 2001 (704 participants from 34 countries/regions) (http://www.kurasc.kyoto-u.ac.jp/ap-rasc/)
- MWRS'01 (URSI Commission F Symposium on Microwave Remote Sensing of the Earth, Oceans, Ice, and Atmosphere combined with the Seventh Specialist Meeting on Microwave Radiometry), Boulder, Colorado, USA, November 5-9, 2001 (150 participants from 20 countries) (http://www.etl.noaa.gov/mrs01) (RSB, March 2002, pp. 57-58)

- Commission F Triennial Open Symposium, Garmisch-Partenkirchen, Germany, February 11-15, 2002 (130 participants from 22 countries) (http://www.dlr.de/HR/URSI-F-2002).

Mr. Hall and Dr. Furuhama emphasised that the reports of Mode B meetings should be made available for publishing in the Radio Science Bulletin.

IV.2 Proposed Commission F Meetings for Next Triennium

The following meetings were preliminarily accepted for Commission F sponsorship. Especially for Mode A, the list is not final. For Mode B, availability of funding limits the number of financially sponsored meetings.

Dr. David Noon volunteered, together with Prof. Dennis Longstaff, to organise the Commission F Triennial Open Symposium in Australia in 2004. Due to a potential conflict with IGARSS'04 (September 2004 in Anchorage, Alaska, USA), it was recommended to hold the meeting in April or May 2004. Volunteers for organising the Commission F Symposium on Microwave Remote Sensing of the Earth, Oceans, Ice, and Atmosphere (to be held early 2005) should contact Prof. Hallikainen.

Mode A:

- MMET: International Conference on Mathematical Methods in Electromagnetic Theory, Kiev, Ukraine, September 10-13, 2002 (http://www.kharkov.ukrtel.net.mmet02)
- The 34th COSPAR Scientific Assembly, Houston, Texas, USA, October 10-19, 2002 (http://www.cosparhq.org)
- Getting the Most out of the Radio Spectrum, London, United Kingdom, October 24-25, 2002 (http://www.iee.org/Events/e24oct02.cfm)
- APMC 2002: 2002 Asia-Pacific Microwave Conference, Kyoto, Japan, November 19-22, 2002 (http://www.apme-mwe.org)
- ISAR-3: Third International School on Atmosphere Radar, ICTP Trieste, Italy, November 25 – December 13, 2002 (http://www.ictp.trieste.it)
- ISAP-i02: Intermediate International Symposium on Antennas and Propagation, Yokohama, Japan, November 26-28,2002 (http://www.icicce.org/cs/ap/ISAP2002)
- ISMOT 2003: Ninth International Symposium on Microwave and Optical Technology, Ostrava, Czech Republic, August 11-15, 2003 (http://www.ismot2003.cz).

Mode B:

- Commission F Triennial Open Symposium, Queensland, Australia, April/May 2004
- ClimDiff03, Fortaleza, Brazil, November 17-19, 2003 (http://www.climdiff.com)
- Specialist Meeting on Microwave Remote Sensing, Rome, Italy, February 2004
- Commission F Symposium on Microwave Remote Sensing of the Earth, Oceans, Ice, and Atmosphere, early 2005
- AP-RASC'04: 2004 Asia-Pacific Radio Science Conference, Beijing, China
- MST: Tenth International Workshop on Technical and Scientific Aspects of MST Radar, Lima, Peru, May 2003.

IV.3 Responsibilities of URSI Representatives at Meetings Sponsored by Commission F

Dr. Furuhama emphasised the importance of the role of Commission F representatives in organising Commission F-sponsored meetings under the three modes of sponsorship: A, B and C. Detailed information and forms for applying for URSI sponsorship and for reporting on the meeting are available on the URSI Home Page (http://www.ursi.org).

V. 2005 General Assembly (New Delhi, India)

Several persons have made proposals for topics of sessions, tutorials and general lectures at the 2005 GA, including Dr. Ed Westwater (USA), Dr. Paolo Pampaloni (Italy), Dr. Alberto Moreira (Germany), Dr. Bertram Arbesser-Rastburg (The Netherlands), Dr. David Noon (Australia) and Prof. Martti Hallikainen (Finland). These proposals will be rationalized and grouped together. Dr. Furuhama requested additional proposals to be sent to Prof. Hallikainen.

V.1 Commission F Sessions

Traditionally, Commission F oral sessions have been organised based on invitation only. It was agreed for the future to open the oral sessions for contributed papers in order to have opportunities especially for Young Scientist Programme awardees to present their results. Each convenor will decide, based on his/her invitations, how many contributed papers he/she can accommodate in the session. The new principle should be clearly stated in the Call for Papers.

Sessions will continue to be organised jointly with other Commissions, when appropriate.

V.2. General Lectures and Commission F Tutorials

No proposals for General Lectures and Commission F Tutorials were made at the Business Meetings, but some have since been received in writing.

VI. Intercommission Working Groups

Dr. Furuhama mentioned that the term of each Working Group automatically ends at a General Assembly unless renewed by Resolution to Council. It was felt that results from Working Groups should be made known through the Radio Science Bulletin, as well as in reports to the Council.

It was agreed to continue WG GF.1 (Middle atmosphere); however, the new abbreviation is GF. It was also agreed to continue WG GFA1, but with the designation FG and title slightly changed. Commission F is to participate in the work of WG HCDFG (Solar power satellite). The Working Groups and Commission F Co-Chairs are:

- FG: Ionosphere and atmosphere remote sensing using satellite navigation systems, Co-Chairs: Bertram Arbesser-Rastburg (F, The Netherlands) and Catherine Mitchell (G, UK)
- GF: Middle atmosphere, Co-Chairs: J. Röttger (G, Germany) and C.H. Liu (F, China SRS)
- HCDFG: Solar power satellite (SPS), Co-Chair for Commission F: Steven Reising (USA).

VII. Representatives to Other Organisations

Dr. Furuhama reminded each representative that they should prepare a report to the 2005 General Assembly.

VII.1 SCOR (Scientific Committee on Oceanic Research)

Commission F interests are looked after by Prof. Piotr Sobieski (Belgium).

VII.2 IUCAF (Inter-Union Committee on Frequency Allocations for Radioastronomy and Space Research)

Commission F to be represented by Dr. Albin Gasiewski (USA). Dr. Furuhama requested him to prepare a report on IUCAF to the Radio Science Bulletin.

VII.3 COSPAR (Committee on SpaceResearch)

Since wave propagation and remote sensing are not among the main topics for COSPAR, it was felt that appointing a Commission F representative is not necessary.

VIII. Publications and Publicity

VIII.1. Review of Radio Science and Commission F Editor (See Section III.1)

VIII.2. Commission F Home Page

Establishing Commission F Home Page was felt necessary for efficient dissemination of information. Prof. Hallikainen agreed to do it. Any material for the Home Page should be sent to him.

VIII.3. Commission F Member Committee Representatives

Dr. Furuhama commented on the problems in contacting some Member Committee Representatives and the fact that certain Member Committees did not even have Representatives for Commission F. He said that information on new appointments should be immediately sent to Prof. Hallikainen (and to URSI Headquarters).

IX. Any Other Business

Mr. Martin Hall, Chair of SCT (Scientific Committee on Telecommunications) told about recent developments in SCT to broaden its activities. The Committee will continue as essentially a liaison committee to exchange information, but active individuals are needed to advance its specific activities. An open meeting on various objectives and relations with ITU was organised during the 2002 General Assembly.

A resolution was put forward to the Council including a change in the Terms of Reference. Commission F expressed its support to the change in the Terms of Reference. {The Council subsequently approved the resolution.} It was agreed that Dr. Jean Isnard (France) should represent Commission F.

BUSINESS TRANSACTED BY COMMISSION G

I. Business Meeting 1: Monday, 16 August 2002

I.1 In Memorium

The business meeting commenced with a brief moment remembering past friends of Commission G. They were Dr Mike Buonsanto, Dr. Yury Chasovitin, Prof. Walter Dieminger, Dr. Andrei I. Galkin, Prof. Yury Illich Galperin, Mr.Nate Gerson, Prof. Dr. Ewald Harnischmacher, Professor Erukhimov Lev Mikhailovich, Prof. Millett Morgan, Prof. Leif Owren, Belyaev Pavel Petrovich, Dr. A. K. Saha, Mr. Arnold Stanbury, Dr. Heinz Thiemann, Dipl.-Phys. H.-U. Widdel.

I.2 Election of Commission G Vice-Chair for 2002-2005

Three candidates were nominated: P. Cannon (UK), K. Oyama (Japan) and B. Zolesi (Italy). Votes were distributedto 43 Commission G national delegates and, including votes cast during the assembly, 25 countries voted with P. Cannon being the successful candidate and K. Oyama second. Subsequently, the URSI council endorsed P. Cannon as the Vice-Chairman of Commission G for 2002-2005.

I.3Terms of reference

The terms of reference of Commission G were reviewed and it was decided that no amendment was necessary.

I.4 Commission G triennial report

The report on commission G activities during the past triennium was prepared by Chairman P. Wilkinson and published well in advance of the General Assembly on the Commission G web site.

I.5 Commission G Working Groups and Joint Working Groups, 1999-2002

All Working Groups triennium reports were included in the Commission triennium report that is available on the Commission G web site. These reports are the responsibility of the lead commission representative. Below the ***current Commission G Working Groups and Joint Working Groups*** are summarized together with brief reports and recommendation for future activity.

G.1. Ionosonde Network Advisory Group (INAG).

Chair: T. Bullett (USA), Vice-Chairs: P. Wilkinson (Australia) and J-C. Jodogne (Belgium).

The last three years have seen a great deal of consolidation in INAG, with all older bulletins placed on the web site and an electronic mailing list set up for communications. Recommend continuing with C. Davies (UK) replacing J-C. Jodogne as vice-chair and P. Wilkinson will be the INAG Bulletin Editor.

G.2. Studies of the Ionosphere Using Beacon Satellites.

Chair: R. Leitinger (Austria), Vice-Chairs: J.A. Klobuchar (USA) and P.V.S. Rama Rao (India).

The two main areas of interest are summarised by the key words 'Electron Content' and 'Scintillations'. One sub-group on Ionospheric Tomography has been created. Recommend continuing with the same officers.

G.3. Incoherent Scatter.

Chair: T. Van Eyken (Norway), Vice-Chair: W. Swartz (USA).

The main objective is to schedule the Incoherent Scatter World Day program. Recommend continuing with W. Swartz becoming chairman and a new vice-chair will be appointed soon.

G.4. Ionospheric Informatics.

Chair: S.M. Radicella (Argentina), Vice-Chair: R. Hanbaba (France).

The work of this working group is now complete. This group has been terminated.

New G.4. Ionospheric Research to Support Radio systems.

Chair: P. Wilkinson (Australia), Co-Chair: M. Angling (UK).

Recommends this working group be formed for the next triennium.

GF. Middle atmosphere.

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

This working group had a successful triennium. Recommend continuing with the same officers.

URSI-COSPAR on International reference Ionosphere (IRI).

Chair: D. Bilitza (USA), Vice-Chair for COSPAR: K.I. Oyama (Japan), Vice-Chair for URSI: B.W. Reinisch (USA).

The main activity of this working group was the development and release of the newest version of the IRI model (IRI-2000). Recommend to continue.

The reports of commissions G and H joint working groups were presented during the joint business meeting on Wednesday, 18 August.

I.6 Publications

The Chair, P. Wilkinson, on behalf of the Commission, thanked the commission G editors for Reviews of Radio Science, J. Sahr (USA), and for Radio Science Bulletin, D. Hysell (USA), for their excellent work.

The proposal to merge both publications was discussed. Review of Radio Science would be incorporated in the Radio Science Bulletin and made primarily available on the web. The URSI General Lectures will be published in the new RSB, together with articles (2 per year) and three reviews submitted by each commission. Questions concerned the possibility of CD distribution (due to downloading time in some countries), visibility of URSI for a web publication versus a printed journal, and the refereeing policy. It was agreed that the proposal was in the right direction.

P. Cannon, the incoming vice-chair of commission G accepted to act as the commission G editor for the new Radio Science Bulletin.

I.7 Commission G resolutions

A resolution on the construction of an incoherent and turbulent scatter sounder in the Antarctic was submitted by the Japanese representative to Commission G, K.I. Oyama. The past Commission G chair, B. Reinisch agreed to examine the wording of this resolution for the commission GH business meeting.

I.8 Discussion on GA 2002 organisation and program

The following issues were raised during the discussion:

- **Submission of abstracts**: length of abstract (1 versus 4 pages), need to submit 1 page abstract followed by 4 page paper. There was a general agreement on having a one-step only submission with a maximum of 4 pages (for possibility of being referred to as a Conference Proceedings).

- **Level of conference fee** considered much too high for some participants
- **Problem of early registration fee** in order to have papers included in the CD-Rom

I.9 Proposals for sessions in 2005

A large number of proposals for sessions had already been received by the Commission Chair, P. Wilkinson. They were presented and a call for further proposals was made. The incoming Chair, C. Hanuise, with the help of present Chair and incoming Vice-Chair, prepared a draft of sessions for GA 2005 for the last business meeting.

I.10 SCT

M. Hall has been tasked to re-activate the Scientific Committee on Telecommunications (SCT). SCT is trying to collect the names of people active in both URSI and one or more of ITU-R, ITU-D and ITU-T. A search for volunteers to represent Commission G commenced.

I.11 Membership of URSI

Information was presented for discussion on the proposal made by the URSI long-range planning committee of adding individual membership for URSI. Individual membership would replace the present system of URSI correspondents. Selection would be made through either national committees or URSI membership committee where selection through national committee is not readily available.

II. Business Meeting 2: Wednesday, 18 August 2002

This business meeting is a joint meeting between commissions G and H.

II.1 Joint Working Groups 1999-2002

Activities during the past triennium and recommendations for future activities were presented for the joint commissions G and H working groups. New Working Groups were also proposed.

GH.1. Active Experiments in Plasmas.

Co-Chair for Com. G: Sa. Basu (USA), Co-Chair for Com. H: T. Leyser (Sweden): Recommend continuing with the same officers.

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

Co-Chair for Com. G: H. Thiemann (Germany), Co-Chair for Com. H: H. Matsumoto (Japan): The work of this group is complete. Both commissions recommend to terminate this group.

HGEJ. Supercomputing in Space Radio Science.

Co-Chair for Com. H: H.Y. Omura, others to be announced.

Commissions G and H recommend forming a new working group replacing the former GH2 working group, and extending the range of work covered.

Proposed Terms of Reference: 1)to promote supercomputing in space plasma physics and space radio engineering, 2) to promote computer simulations by training young scientists in the field of space radio science, 3) to promote international collaboration and projects of supercomputing in space radio science

GHC. Wave and Turbulence Analysis.

Co-Chair for Com. H: T. Dudok de Wit (France), Co-Chair for Com. C: G.C. Kubin (Austria), Co-Chair for Com. G: David Hysell (USA): It is proposed that the inter-commission links of this group are extended (HGJC) and the lead commission altered, Com. H becoming the lead commission.

URSI/IAGA VLF/ELF Remote Sensing of the Ionosphere and Magnetosphere (VERSIM).

Co-Chair for URSI Commissions G and H: M. Parrot (France); Co-Chair for IAGA Commissions 2 and 3: A.J. Smith (UK): Recommend continuing with the same officers.

EGH. Seismo-electromagnetics.

Co-Chair for Com. H: M. Parrot (France). Endorsed by Commissions G and H.

Inter-commission Working Group on Solar Power Satellites.

Chair: H. Matsumoto (Japan). Commission G representative: M. Rietveld (Germany). Endorsed by Commissions G and H.

II.2 Proposals for joint G/H sessions in 2005

The following joint symposia were suggested for the General Assembly in 2005:

- Data analysis techniques for diagnosing plasma fluctuations with radio methods (H: T. Dudok de Wit, G: A. Wernik, J: tbd, C: G. Kubin)
- Dusty plasmas (H leading)
- ULF/VLF impacts on the radiation belts
- Image (R. Benson, J. Green)
- Waves and boundaries
- Deep(Space active and passing probing (H: B. Thide, G: tbd, J: tbd)
- Lightning - Ionosphere interactions (H: V. Pasko)
- Radiation belts (H: R. Horne)

II.3 Notice of Commissions G and H resolutions

The resolution presented by Japan on building an Incoherent Scatter Radar in the Antarctic was supported by both commissions G and H.

II.4 Proposed URSI Representatives

Commissions G and H recommended the following representatives:

- COSPAR: Dr Klos for a second term.
- IUCAF: G. Wannberg (Sweden). T. Van Eyken has resigned from this group.
- ISES: S. Pulinets (Russia) for Com. G, with R. Pirjola (Com. E, Finland) being the second representative.
- SCAR: A. Smith (UK) for a second term.

- SCOSTEP: S. Avery (USA) for a second term.
- SRAMP: Su. Basu (USA) until SRAMP is terminated in this triennium. Recommend that Su. Basu (USA) become the URSI representative on the new SCOSTEP initiative, CAWSES (Climate And Weather of the Sun-Earth system).
- SCT: P. Lassudrie-Duchesne (France) for Commission G.

II.5 Proposals for ICS (ICSU) projects

ICS (former ICSU) has shifted its financial support towards granting funds to interdisciplinary projects, preferably within thematic programs defined by ICSU. These projects should be inter-union in order to have a better chance of being funded. Deadline for submission of grant proposals to ICSU is February.

II.6 Other business

There was no time to discuss any other business during the meeting.

III. Business Meeting 3: Friday, 20 August 2002

III.1 Commission G sessions for GA 2005

The incoming Chair, C. Hanuise presents the draft session list and convenors for the 2005 General Assembly. It tries to cover as much as possible all interests within Commission G and to involve convenors from younger scientists and various countries.

Sessions with Commission G leading:

- G(1). Imaging of the ionosphere. Includes data driven, assimilation and other techniques. Convenors: B. Wilson (USA), M. Cordrescu (USA), C. Mitchell (UK).
- G(2). Ionospheric effects on radio systems. Includes all latitude propagation, HF and transionospheric. Convenors: Chandra (India), P. Lassudrie (France).
- GF(3). Remote sensing using global navigation satellite systems. Convenors: N. Jakowski (Germany), P. Spalla (Italy).
- G(4). Computation and networking in ionospheric radar systems. Includes coherent and incoherent scatter, ionosondes, etc Convenors: J. Sahr (USA), K. Oyama (Japan).
- G(5). Electron density profiling and validation. Incoherent scatter, ionosondes, occultation, comparisons between different techniques, and models, etc. Convenors : J. Foster (USA), D. Bilitza (USA).
- G(6). Open session and latest results. Convenors: P. Wilkinson (Australia), J. Wu (China).
- G(7). Small-scale structures in the ionosphere. Convenors: J.P. St Maurice (Canada), J. Chau (Peru).
- GHJ(8). Novel ground-based radio techniques for studying the sun-earth plasma environment. Includes meteors. Convenors: C. Hanuise (G, France), B. Thide (H, Sweden), J (to be decided).
- GP(9). Combined poster session. Convenors: P. Cannon (UK), B. Zolesi (Italy).

Sessions with other commissions leading:

- FG. Transionospheric signal degradation. Convenors: A. Coster (G, USA), R. Leitinger (G, Austria), F tbd.
- HG(1). Radio-frequency observations in space. Convenors: B. Reinisch (G, USA), G.James (H, Canada).
- HG(2). Ionospheric modification by high power radio waves: coupling of plasma processes. Convenors: T. Leyser (H, Sweden), Sa. Basu (G, USA).
- HGCJ. Data analysis techniques for diagnosing plasma fluctuations with radio methods. Convenors: T. Dudok de Wit (H, France), A. Wernik (G, Poland).
- HGE. Ionospheric effects of lightning. Convenors: E. Blanc (G, France), others tbd.

Suggestions for Commission G tutorial at GA 2005:

- Space weather: basic processes, effects.
- Ionospheric effects on spaced-based systems and GPS related topics.
- Highlights in ionospheric theory and experiment from 1925 to 2005.
- Mechanisms of HF wave attenuation in the ionospheric plasma.
- Use of the regularization methods for the inverse problem of ionospheric radio sounding.
- Imaging techniques for ionospheric studies.
- Satellite observation of lightning.
- Modelling the topside and plasmasphere.
- Introduction to GPS remote sensing.

Suggestion for commission G General Lecture at GA 2005:

- Peculiarities of electromagnetic wave propagation in non-stationary environments.
- Space weather and human health.
- Present and future applications of GNSS.

III.2 Publications

The incoming Vice-Chair, P. Cannon was confirmed as the Commission G editor for the new Radio Science Bulletin, incorporating the Review of Radio science.

The first paper submitted by Commission G will be the tutorial lecture given by J.P. St Maurice on 'Ionospheric Irregularities'. Further contributions are requested.

III.3 Review of GA 2002

The General Assembly was quite successful for Commission G. Several sessions attracted over 100 scientists, many from other commissions.

III.4 Resolutions

It was recalled that Commissions G and H passed the following Commission resolution at their joint business meeting "***Incoherent and Turbulent Scatter Sounding in the Antarctic Commission G Ionosphere***"

Considering

a. that important parameters describing the ionosphere and the atmosphere can be obtained by using the incoherent scatter sounding technique;
b. that there is no such sounder in the Antarctic region;

c. that such a sounder would help to improve our understanding of the Earth's environment and its changing climate, and especially the structure and dynamics of the whole atmosphere including lower, middle and upper atmosphere;

resolves to urge the scientific community to construct an incoherent scatter sounding station in Antarctica.

III.5 Closing Comments

At the conclusion of this meeting, the outgoing Chair, P. Wilkinson, thanked the commission for the support they have given to him during his tenure and especially for the assistance given by the incoming Chair, C. Hanuise and the Vice Chair, P. Cannon during the General Assembly. The incoming Chair, C. Hanuise, then acknowledged the work put by P. Wilkinson and thanked him for his efforts and expressed the pleasure he had working with him, as well as expressing his pleasure at being the incoming Chair.

IV. Sessions held in the 2002 General Assembly

IV.1 Tutorial

GT. Ionospheric Irregularities. J.P. St Maurice (Canada)

IV.2 Sessions organized by Commission G or with Commission G leading

- G1. Ionospheric effects on HF propagation. Convenors: P. Cannon (UK), L. Bertel (France): 12 papers.
- G2. Operational ionospheric models including data ingestion. Convenors: D. Bilitza (USA), K. Igarashi (Japan): 10 papers.
- G3. Open session and latest results. Convenors: B. Reinisch (USA), A. Belehaki (Greece): 7 papers.
- GP1. General Poster Session. Convenor: E. Blanc (France): 110 papers
- GP2. Short term variability in the ionosphere. Convenor M. Cordrescu: 11 papers
- GF. Transionospheric signal degradation. Convenors: R. Leitinger (G, Austria), M. Cervera (G, Australia), B. Arbesser-Ratsburg (F, Netherlands), D.V. Rogers (F, Canada): 10 papers.
- GH1. Ionospheric modification by high power radio waves: coupling of plasma processes. Convenors: Sa. Basu (G, USA), T.B. Leyser (H, sweden): 11 papers.
- GH2. Topside Ionosphere and Plasmasphere. Convenors: J. Foster (G, USA), I. Kilura (H, Japan): 7 papers.
- GHE. Space weather effects on systems. Convenors: P. Wilkinson (Australia), A. Hilgers (H, Netherlands): 11 papers.
- GJ. New approaches to radio sensing of the terrestrial plasma environment. Convenors: C. Hanuise (G, France), J. Röttger (G, Germany), C. Lonsdale (J, USA): 17 papers.

IV.3 Sessions with Commission G participation

- EGH. Lithosphere-Atmosphere-Ionosphere coupling. Convenors: M. Hayakawa (Japan), S. Pulinets (G, Russia): 7 papers.
- FG. Wave propagation for satellite navigation and mobile services. Convenors: B. Arbesser-Rastburg (F, Netherlands), D.V. Rogers (F, USA), R. Leitinger (G, Austria), M. Cervera (G, Australia): 10 papers.
- HG1. Spacecraft and ground-based observations of stimulated and natural space-plasma waves. Convenors: K. Hashimoto (H, Japan), R.R. Anderson (H, USA): 10 papers
- HG2. Experiments in space and laboratory plasmas. Convenors: W.E. Amatucci (H, USA), R. Hatakeyama (H, Japan): 7 papers
- HGE1. Lightning effects in the ionosphere and radiation belts. Convenors: S.A. Cummer (H, USA), C.J. Rodger (G, New Zealand): 10 papers.
- HGE2. Dynamics of dusty plasmas in space and laboratory. Convenors: G. Ganguli (H, USA), S. Avery (G, USA): 7 papers
- HGJC. Analysis methods for plasma waves and turbulence. Convenors: T. Dudok de Wit (H, France), A. Wernik (G, Poland): 6 papers.

UNION RESOLUTIONS & RECOMMENDATIONS ADOPTED AT THE MAASTRICHT GA

U.1 International Radio Quiet Reserves

The URSI Council,

Considering that:

a) to explore the far reaches of the Universe, a limited number of very large, extremely sensitive radio telescopes is being planned for construction in the coming 10 - 20 years;

b) because the spectral features of distant sources are shifted in frequency by the universal cosmic expansion to well outside the frequency bands allocated to the Radio Astronomy Service, these new radio telescopes will need to operate across a wide range of spectrum;

c) such telescopes will therefore be extremely vulnerable to interference from emissions from space stations, especially those using non-geostationary satellites;

d) the current Radio Regulations make no provision for protecting radio astronomical observation outside the designated frequency bands;
e) developing such protection will involve cross-sectoral issues in the areas of global telecommunications, international trade, regulation of radio spectrum utilization, as well as scientific research, which issues taken together lie outside the competency of any single existing regulatory body;
f) the inter-governmental Global Science Forum of the OECD has therefore sponsored a Task Force on Radio Astronomy and the Radio Spectrum, which has brought together international experts drawn from the telecommunications satellite industry, the radio spectrum regulatory community, and the radio astronomical research community, to consider whether this diversity interests might be reconciled;
g) said Task Force has made proposals to this end, including a proposal for a small number of internationally recognized radio quiet reserves in which the planned new radio telescopes might be located;
h) although designation of such reserves is not within the established procedures of the ITU, that body currently provides the most appropriate forum in which to consider the possibility;

Recommends that:
1) the draft agenda of the WRC-2006 include the following item: "To consider the possibility of creating one or more internationally recognized radio quiet reserves, and take appropriate action."
2) the ITU-R undertake the necessary preparatory studies, possibly soliciting input from the Scientific Committee on Telecommunications of URSI, the Commission on Frequency Allocations for Radio Astronomy and Space Science (IUCAF) of ICSU, and other bodies of experts as appropriate.

U.1 Zones internationales de silence radio

Le Conseil de l'URSI,

Considérant que :
a) dans le but d'explorer l'Univers lointain, la construction d'un nombre limité de très grands télescopes à haute sensibilité est prévue au cours des 10 à 20 prochaines années ;
b) du fait de l'expansion cosmique, la fréquence des raies spectrales des sources éloignées est déplacée bien en dehors des bandes de fréquence attribuées au Service de radioastronomie et, par conséquent, ces nouveaux radiotélescopes devront fonctionner dans une large gamme de fréquence ;
c) de tels télescopes seront dès lors extrêmement vulnérables aux interférences provoquées par les émissions des stations spatiales, et plus particulièrement celles des satellites non-géostationnaires ;
d) les réglementations actuelles en matière d'ondes radio ne prévoient aucune disposition concernant la protection des observations radioastronomiques en dehors des bandes de fréquence désignées ;
e) le développement d'une telle protection soulèvera des questions intersectorielles dans les domaines des télécommunications à l'échelle mondiale, du commerce international, de la réglementation de l'exploitation du spectre radio et de la recherche scientifique, lesquelles questions, considérées dans leur ensemble, ne relèvent de la compétence exclusive d'aucun organisme de réglementation existant ;
f) le Forum mondial de la science de l'OCDE a, à cette fin, parrainé un groupe de travail sur la radioastronomie et le spectre radio, qui a rassemblé des experts internationaux provenant de l'industrie des télécommunications par satellite, de la communauté de réglementation du spectre radio et de la communauté de recherche radioastronomique, afin d'examiner si les différents intérêts étaient conciliables ;
g) ledit groupe de travail a formulé des propositions dans ce sens, dont l'une vise à prévoir un petit nombre de zones de silence radio reconnues à l'échelle internationale dans lesquelles les nouveaux radiotélescopes en projet pourraient être construits ;
h) bien que la désignation de telles zones ne s'inscrive pas dans les procédures établies de l'UIT, cet organisme semble constituer le forum le plus adéquat pour envisager cette possibilité ;

Recommande que :
a) le projet d'ordre du jour de la réunion WRC-2006 contienne le point suivant : «Prise en considération de la création éventuelle d'une ou plusieurs zones de silence radio reconnues à l'échelle internationale et adoption de mesures appropriées».
b) l'ITU-R entreprenne les études préparatoires nécessaires, en sollicitant éventuellement la participation du Comité scientifique sur les télécommunications de l'URSI, de la Commission inter-Unions pour l'allocation des fréquences à la radioastronomie et aux sciences spatiales de l'ICSU (IUCAF) et, le cas échéant, d'autres groupes d'experts.

U.2 Establishment of a working group on the possible redefinition of UTC

The URSI Council,

Considering
a) That in 1971, the ITU-R (International Telecommunications Union - Radiocommunications, formerly the CCIR, the International Consultative Committee for Radiocommunications) proposed the present form of UTC, based upon the SI second but linked to the variable rotation of the Earth through the introduction of leap seconds in such a manner that |UT1-UTC| will always be less than 0.9 seconds,

b) That while this system has worked well for most purposes, the future implementation of satellite and other systems may not easily incorporate the leap second system,
c) That the ITU-R has formed a Special Rapporteur Group to study a possible change in the definition of UTC, and that this Special Rapporteur Group has asked URSI and other international bodies to advise it,
d) That a committee formed by URSI Commission J has conducted a survey of the effects of a redefinition of UTC, and delivered that report to the Committee Chair, and
e) That this report found no systems maintained by URSI members that would be adversely affected should UTC be redefined by fixing the number of leap seconds to its current value, or its value at any future date,
f) That discussion of possible redefinition of UTC has important significance to URSI;
   - That a large number of non-URSI members voiced strong objections to any change, citing the inconvenience to amateur astronomers along with possible legal or philosophical objections, and
   - That all URSI members may not have had a chance to respond, or might respond differently if polled today;

Resolves
1) That an URSI-wide working group be formed to inform and poll the URSI membership,
2) That the chair of this working group act as URSI representative to the ITU/R Special Rapporteur Group, and
3) That this working group be requested to prepare a resolution for the URSI General Assembly of 2005.

U.2 Création d'un groupe de travail sur la redéfinition éventuelle du TUC

Le Conseil de l'URSI,

Considérant
a) Qu'en 1971 l'UIT-R (l'Union Internationale des Télécommunications-Secteur des Radiocommunications, anciennement CCIR) a proposé la réalisation actuelle du TUC (temps universel coordonné), laquelle est basée sur la seconde SI, mais liée à la rotation variable de la Terre par l'introduction de secondes intercalaires, de sorte que |UT1-TUC| soit toujours inférieur à 0.9 seconde.
b) que si ce système a bien fonctionné dans son ensemble, le développement futur des systèmes satellites (et autres) pourrait ne pas facilement s'accomoder du système de la seconde intercalaire.
c) que l'UIT-R a formé un groupe chargé d'étudier la possibilité d'un changement de définition du TUC, et que ce groupe a demandé l'avis de l'URSI, ainsi que celui d'autres institutions internationales.
d) qu'un comité formé par la Commission J de l'URSI a fait un relevé des effets d'une nouvelle définition du TUC, et a envoyé un rapport à ce sujet au Président du Comité UIT-R.
e) que ce rapport conclut qu'aucun des systèmes utilisés par les membres de l'URSI ne subirait d'effets adverses suite à une définition qui fixerait le nombre de secondes intercalaires à sa valeur présente, ou à sa valeur à une date future.
f) que la possibilité d'une nouvelle définition du TUC est un sujet d'importance pour l'URSI
   - qu'un nombre considérable de personnes qui ne sont pas membres de l'URSI ont formulé de fortes objections à tout changement, citant en particulier les problèmes que pourraient connaître les astronomes-amateurs, ainsi que les objections légales et philosophiques que le changement pourrait créer;
   - que tous les membres de l'URSI n'ont peut-être pas eu la possibilité de réagir, et que ceux qui l'ont fait pourraient avoir changé d'avis depuis

décide
1) de former un groupe de travail « URSI », chargé d'informer les membres de l'URSI et de recueillir leurs réactions,
2) de charger le Président de ce groupe de travail de représenter l'URSI au sein du groupe UIT-R susnommé,
3) de demander à ce groupe de travail de préparer une résolution destinée à l'Assemblée Générale de l'URSI de 2005.

U.3 Setting up of a team for an effective collaboration with ITU

The URSI Council,

Considering
a) that the Scientific Council on Telecommunications (SCT), was "reactivated", following the U7 Resolution decided at the Toronto General Assembly in 1999 ;
b) that, taking into account the development of manifold applications of the radio-communications, it is urgent to implement the general terms of reference of this resolution in a practical and sustainable way
c) that this implementation must be active and participatory in the ITU Working Parties (WP), considering the complexity of the subjects, the scientific and economic stakes and the fast technical developments;
d) that the current participation of URSI Correspondent Members is on a thoroughly individual basis, each participant in his/her field of interest and without general co-ordination;
e) that only a team of selected people can satisfactorily and perseveringly cover the totality of subjects related to the use of the electromagnetic spectrum interesting URSI and undertake concerted actions;

Resolve
1) that a team be set up under the responsibility of the SCT in order to effectively and sustainably implement collaboration between ITU and URSI as defined in the terms of reference of the U7 Resolution;

2) that it consists of URSI Correspondent Members who already participate in ITU Working Parties;
3) that in a combined effort under the auspices of SCT, they participate in the various working groups of ITU depending on their competencies or related fields when necessary in order to both represent the positions of URSI in these groups and to put together a synthesis of works in progress for the benefit of URSI Commissions via SCT;
4) that their activities be known by URSI Commissions on the one hand, and IUT on the other hand and that relevant documentation be addressed to URSI and ITU Boards;
5) that each member knows his/her counterpart in his/her National Frequency Agency, so that URSI positions be acknowledged by these Agencies;
6) that upon request of SCT, this team is responsible for giving scientific advice in response to questions addressed by ITU to URSI.

U.3 Création d'un organe collégial de collaboration avec l'UIT

Le Conseil de l'URSI,

Considérant
a) que le Conseil Scientifique sur les Télécommunications (SCT), a été «réactivé», suite à la Résolution U7 décidée à l'Assemblée Générale à Toronto en 1999 ;
b) que, compte tenu du développement des nombreuses applications des radiocommunications, il y a urgence de mettre en œuvre de façon pratique et durable les termes généraux de référence de cette résolution ;
c) que cette mise en œuvre doit se faire par une participation active et suivie dans les Groupes de Travail (WP) de l'UIT, en raison de la complexité des sujets, des enjeux scientifiques, économiques, et du rythme des évolutions ;
d) que la participation actuelle de Membres Correspondants de l'URSI, se fait à titre individuel, chacun dans le domaine de son activité professionnelle, et sans concertation générale ;
e) que seule une équipe de personnes mandatées peut couvrir, de manière satisfaisante et dans la durée, l'ensemble des sujets liés à l'utilisation du spectre électromagnétique intéressant l'URSI et avoir des actions concertées

Recommande
1) qu'un organe collégial soit créé sous la responsabilité du SCT afin de mettre en œuvre, effectivement et dans la durée, la collaboration entre l'UIT et l'URSI telle qu'elle est définie dans les termes de référence de la Résolution U7 ;
2) qu'il soit constitué des Membres Correspondants de l'URSI participants effectivement aux groupe de travail de UIT ;
3) que, de manière collégiale sous l'égide du SCT, ils participent aux différents groupes de travail de l'UIT dans leurs domaines de compétence ou dans des domaines connexes lorsque c'est nécessaire pour que, d'une part, les positions de l'URSI y soient présentées et, d'autre part, qu'ils puissent établir une synthèse des travaux en cours au profit des Commissions de l'URSI via le SCT ;
4) que leurs activités soient connues des Commissions de l'URSI, d'une part, et de l'UIT, d'autre part et que des rapports de synthèse soit adressés aux Bureaux de l'URSI et de l'UIT ;
5) que chaque membre ait avec l'Agence des Fréquences de son Etat un correspondant identifié pour que les positions de l'URSI soient connues des Agences et comprises par elles ;
6) que cet organe collégial ait la responsabilité, sur demande du SCT, d'élaborer les avis scientifiques en réponses aux questions posées par l'UIT à l'URSI.

U.4 Communication with URSI Board

The URSI Council,

Considering:
a) That it is of the highest importance that a close contact be maintained between the Board of URSI on the one hand, representatives of the Member Committees, Chairs and Vice- Chairs of Commissions and Members of the Standing Committees, on the other hand;
b) That this proximity and this reciprocal communication among the various structures of URSI allows the efficient support of the Board;
c) That current information and communication technologies make it possible, at low cost and without excessive effort, to implement these principles;

Recommend:
1) That the annual calendar of meetings of the Board of URSI be known to the representatives of the Member Committees, Commission Chairs and Vice-Chairs and members of the standing committees by any means chosen by the Board;
2) That the agenda of meetings of the Board be sent as soon as possible to the persons defined in article (1) to permit reciprocal communication;
3) That the reports of these meetings be sent to the people defined in article (1) as soon as possible.

U.4 Communication avec le Bureau de l'URSI

Le Conseil de l'URSI

Considérant :
a) Qu'il est de la plus haute importance qu'un contact étroit soit maintenu entre le Bureau de l'URSI d'une part, les représentants des Comités Membre, les Présidents et vice-Présidents de commission et les membres des comités permanents d'autre part ;
b) Que cette proximité et cette communication réciproque des différentes structures de l'URSI entre elles permet d'apporter une aide efficace au bureau ;

c) Que les technologies actuelles de l'information et de la communication permettent, à faible coût et sans lourdeur excessive, de mettre en œuvre ces principes ;

Recommande :

1) Que le calendrier annuel des réunions du Bureau de l'URSI soit connu des représentants des Comités Membre, des Présidents et vice-Présidents de commission et des membres des comités permanents par tout moyen choisi par le bureau ;
2) Que l'ordre du jour des réunions de Bureau soit adressé aussitôt que possible aux personnes définies à l'article (1) pour permettre une communication réciproque ;
3) Que le compte rendu de ces réunions soit adressé aux personnes définies à l'article (1) dans les meilleurs délais.

U.5 Inter-Commission Working Group on the Middle Atmosphere

The URSI Council,

Recognising the importance of studies of the middle atmosphere for understanding the global change problems;

Noting

- that proven techniques exist for applying electromagnetic waves to investigate
  (i) the physics and chemistry of the middle atmosphere,
  (ii) the coupling of the middle atmosphere to regions above and below;
- that these topics are included in the terms of reference of both Commissions G and F;

Resolve to establish an Inter-Commission Working Group on the Middle Atmosphere, with the following terms of reference

- to co-ordinate within URSI and with other ICSU bodies the relevant activities for studies of the middle atmosphere;
- to estimate research for understanding both the dynamic processes in the middle atmosphere and the climatology of these regions, and to cover, for instance, the development and application of :
  (i) MST and related radar and radio techniques,
  (ii) Lidar and related optical techniques, and
  (iii) satellite-borne and ground-based passive remote sensing techniques.

U.5 Groupe de Travail Intercommissions sur l'Atmosphère Moyenne

Le Conseil de l'URSI,

Reconnaissant l'importance des études de l'atmosphère moyenne pour comprendre les problèmes de changement global ;

Notant

- que des techniques éprouvées existent pour appliquer les ondes électromagnétiques à l'étude
  (i) de la physique et de la chimie de l'atmosphère moyenne,
  (ii) du couplage de l'atmosphère moyenne avec les régions d'altitudes inférieure et supérieure ;
- que ces sujets font partie des termes de référence des deux commissions G et F ;

Décide d'établir un Groupe de Travail Inter-commissions sur l'Atmosphère Moyenne, avec les termes de référence suivants :

- Coordonner au sein de l'URSI et avec les autres membres de l'ICSU les activités associées aux études de la moyenne atmosphère ;
- Estimer les recherches nécessaires à la compréhension des processus dynamiques de l'atmosphère moyenne et de la climatologie de ces régions, et couvrir, par exemple, le développement et l'application :
  (i) des radars MST et autres techniques radios,
  (ii) des lidars et autres techniques optiques, et
  (iii) des techniques de télédétection passives satellitaires ou au sol.

U.6 Inter-Commission Working Group on Atmospheric RemoteSensing using Satellite Navigation System

The URSI Council,

Considering

- the importance of using space- and ground-based observations of GPS and GLONASS signals to monitor the global environment of the atmosphere;
- the use which future spaceborne observations of the temperatures of the lower atmosphere and the electron densities of the ionosphere will make of this technique;

resolves to establish an Inter-Commission Working Group on Atmospheric Remote Sensing and propagation research using Global Positioning Systems (GPS / GLONASS), with Bertram Arbesser-Rastburg (ESA, Netherlands) as Coordinator and Cathryn Mitchell (United Kingdom) as the Commission F representative.

U.6 Groupe de Travail Intercommissions sur la Télédétection Atmosphérique à l'aide de Systèmes de Navigation par Satellite

Le Conseil de l'URSI,

Considérant

- l'importance d'utiliser les observations dans l'espace et au sol des signaux GPS et GLONASS pour surveiller l'environnement global de l'atmosphère,

- l'utilisation que les futures observations spatiales de la température de la basse atmosphère et des densités électroniques de l'ionosphère feront de cette technique ;

Décide d'établir un Groupe de Travail Inter-commissions sur la Télédétection Atmosphérique et la Propagation à l'aide des Systèmes de Positionnement par Satellite (GPS/GLONASS), avec, pour coordinateur, Bertram Arbesser-Rastburg (ESA, Pays-Bas) et, pour représentant de la commission F, Cathryn Mitchell (Royaume Uni).

U.7 URSI Radioscientist

The URSI Council,
having considered the report of the Long Range Planning Committee

resolves to accept the recommendation of the Long Range Planning Committee to request the Board to implement the "URSI Radioscientist" status (replacing the concept of "URSI Correspondent").

U.7 Radioscientifique URSI

Le conseil de l'URSI,

Ayant examiné le rapport du Comité de Planification à Long Terme

Décide d'accepter la recommandation du Comité de Planification à Long Terme demandant au Bureau de mettre en place le statut de 'Radioscientifique URSI' (remplacant le concept de 'Correspondant URSI')

U.8 URSI Travelling Lecturer Program

The URSI Council,

having considered the report of the Long Range Planning Committee

resolves to accept the recommendation of the Long Range Planning Committee to request the Board to implement an "URSI Travelling Lecturer" program.

U.8 Programme de Conférencier de l'URSI

Le Conseil de l'URSI,

Ayant examiné le rapport de Comité de Planification à Long Terme

Décide d'accepter la recommendation du Comité de Planification à Long Terme demandant au bureau de mettre en place un programme de 'Conférencier URSI'

U.9 XXVIIIth General Assembly

The URSI Council,
having considered the invitations for the XXVIIIth General Assembly which had been submitted by the URSI Member Committees in China (Beijing), India (New Delhi) and the USA (Denver, Colorado);

resolves
1. to accept the invitation of the Indian URSI Committee to hold the XXVIIIth General Assembly in New Delhi in October 2005;
2. to record its thanks to the Member Committees in China (CIE) and in the U.S.A. for their invitations.

U.9 XXVIIIe Assemblée générale

Le Conseil de l'URSI,

Ayant examiné les invitations pour la XXVIIIe Assemblée générale soumises par les comités membres de l'URSI en Chine (Pekin ou Beijing), Inde (New Delhi) et aux Etats-Unis (Denver, Colorado) ;

décide
1. d'accepter l'invitation du comité indien de l'URSI pour organiser la XXVIIIe Assemblée générale à New Delhi en octobre 2005;
2. d'adresser aux comités membres en Chine (CIE) et aux Etats-Unis ses remerciements pour leurs invitations.

U.10. Vote of Thanks to the Dutch URSI Committee

The URSI Council,

resolves unanimously to convey to the Dutch URSI Committee its warm thanks and appreciation for the organisation of the XXVIIth General Assembly in Maastricht.

U.10 Remerciements au Comité néerlandais de l'URSI

Le Conseil de l'URSI,

Décide à l'unanimité de transmettre au comité néerlandais ses vifs remerciements et son appréciation pour l'organisation de la XXVIIe Assemblée générale à Maastricht

COMMISSION RESOLUTIONS ADOPTED AT THE MAASTRICHT GA

C.1 Incoherent and Turbulent Scatter Sounding in the Antarctic

Commissions G and H,

Considering
(a) that important parameters describing the ionosphere and the atmosphere can be obtained by using the incoherent scatter sounding technique;
(b) that there is no such sounder in the Antarctic region;
(c) that such a sounder would help to improve our understanding of the Earth's environment and its changing climate, and especially the structure and dynamics of the whole atmosphere including lower, middle and upper atmosphere;

resolves to urge the scientific community to construct an incoherent scatter sounding station in Antarctica.

C.1 Sondage par diffusion incohérente et turbulente en Antarctique

Les Commissions G et H,

Considérant
(a) que des paramètres importants pour la description de l'ionosphère et de l'atmosphère peuvent être obtenus par la technique de sondage par diffusion incohérente,
(b) qu'il n'existe pas de tel sondeur dans la région antarctique,
(c) qu'un tel sondeur aiderait à améliorer notre compréhension de l'environnement terrestre et de ses changements climatiques, et plus particulièrement la structure et la dynamique de la basse, moyenne et haute atmosphère ;

Décide d'inciter la communauté scientifique à construire une station de sondage par diffusion incohérente en Antarctique.

C2. Resolution to Inter-Commission Working Group on SPS (Solar Power Satellites)

Commission H,
Considering,
a) that SPS research has become increasingly important for a possible clean power supply for mankind and that one of the key issues of the SPS is microwave power transmission (MPT) from space to earth,
b) that URSI – which covers various fields related to MPT – should contribute to the SPS,
c) that MPT technology has not yet been explicitly covered by the existing commissions although there is emerging interest by a number of commissions, and
d) that this field has so far been covered by a Union Session at the AP-RASC meeting and H Special Session at this meeting,

Resolves
1) that in addition to SPS technologies and science, other related issues such as interference and compatibility of SPS with environments should be discussed,
2) that an IWG to discuss all aspects of SPS and MPT should be created, and
3) that the IWG should contribute to assessment of the present MPT technologies and development of new ones and clarification and reduction of interference caused by SPS.

C2. Résolution sur un Groupe de Travail Inter-Commissions sur les SES (Satellites d' Energie Solaire)

La Commission H,

Considérant,
a) que la recherche en SES est devenue de plus en plus importante en vue d'une source possible d'énergie propre pour l'humanité et que l'un des problèmes clés est le transmission d'énergie micro-onde (TEM) entre l'espace et le sol,
b) que l'URSI – qui couvre divers domaines reliée à la TEM- devrait contribuer aux SES,
c) que la technologie de TEM n'a pas encore explicitement du ressort des commissions existantes, bien qu'il y ait un intérêt émergeant dans plusieurs commissions, et
d) que ce domaine a été jusqu'à présent couvert par une session de l'Union au congrès AP-RASC et une session Spéciale H à ce congrès,

Décide
1) qu'en plus des technologies et de la science des SES, des problèmes reliés tels les interférences et la compatibilité des SES avec les environnements doivent être discutés,
2) qu'un groupe de travail inter-commissions doit être crée afin de discuter tous les aspects des SES et des la TEM
3) que le groupe de travail inter-commissions doit contribuer à l'évaluation des technologies actuelles des SES et au développement de nouvelles ainsi qu'à la clarification et à la réduction des interférences provoquées par les SES.

Conferences

CONFERENCE REPORTS

Session C4.3 of the COSPAR World Space Congress

Houston, Texas, USA, 17-18 October 2002

WSC (World Space Conference) Session C4.3 was organized by the URSI/COSPAR Working Group on the International Reference Ionosphere (IRI), with the goal of reviewing ongoing ionospheric modeling activities, with a special emphasis on efforts that involve the IRI model. The session included 28 oral and 12 poster presentations. Unfortunately, two key speakers were unable to attend, because of visa problems. Special meetings of the IRI Working Group to discuss the status of the IRI model and future improvements were held from 12:30 to 2:00 pm on October 17, and from 16:00 to 17:00 pm on October 18. Financial support was provide by COSPAR and URSI.

Electron Density up to F Peak

M. Friedrich (Austria) presented models for the quiet and disturbed auroral D region, based on rocket and EISCAT measurements. The quiet-time model describes the changes at constant-pressure surfaces in terms of solar zenith angle and solar activity (this will be included in the next version of the IRI). The disturbed model additionally relies on riometer absorption measurements and Kp, to describe D-region changes during disturbed conditions. The nighttime E region (peak and valley) remains a problem, because of the scarcity of data. For the F2 peak, E. Araujo-Pradere (NOAA, USA) evaluated the new IRI storm-time correction model for foF2 with data from the worldwide ionosonde network, for all storm events in 2000/2001. He found an improvement of about 50% when using the new model, instead of the uncorrected old model. For the F2 peak height, hmF2, comparisons at low-latitude ionosonde stations in Africa (J. Adeniyi, Nigeria; O. Obrou, Ivory Coast), China (M. Zhang, CAS, Beijing), and South America (R. Ezquer, Argentina) showed that the IRI underestimates the ionosonde-deduced heights by several tens of km.

Topside and Plasmasphere

D. Bilitza (GSFC, USA) presented a correction function for the IRI topside model that resulted in excellent agreement with Alouette/ISIS topside-sounder measurements. It was decided to include this corrected topside model as a new option in the next version of the IRI. Shortcomings of the current IRI topside model were also noted in comparisons with electron densities deduced from CHAMP occultation measurements (N. Jakowski, Germany). B. Reinisch (UML, USA) presented an empirical plasmaspheric model, based on data obtained from the Radio Probe Instrument (RPI) on the Image satellite. Other candidates for the IRI plasmasphere are the models by D. Gallagher (MSFC, USA), P. Webb (New Zealand), and T. Gulyaeva (Russia). Using data from Athens and Millstone Hill, A. Belahaki (Greece) showed that ground-based ionograms provide a reliable estimate of the electron-density profile above the F2 peak. Using ROCSAT-1 data, S.-Y. Su (China SRS) studied the occurrence of equatorial spread F (ESF) in relation to the along-track density gradients, and established thresholds above which ESF is very likely to occur.

Plasma Temperatures

Several new temperature models were introduced in this session. K. Oyama (Japan) presented electron-temperature models for low-latitudes at 600 km, based on Hinotori satellite data, and for plasmaspheric altitudes, based on Akebono satellite measurements. Millstone Hill incoherent scatter data from 1976 to 2001 were the basis for a station-specific model describing variations with time, altitude, season, and solar activity (S. Zhang, USA). K. Mahajan (India) used radar data from Arecibo to highlight the seasonal and solar-cycle variations of electron temperature, and the close correlation with electron density. One of the major shortcomings of the present IRI electron-temperature model is the fact that it does not include variations with solar activity. An effort is planned to develop a new temperature model that will include these variations, based on inputs from the various mission-specific and station-specific models (V. Truhlik, D. Bilitza, K. Oyama).

Ion Composition

The current IRI ion-composition model of the topside ionosphere was built with only a small amount of satellite and high-apogee rocket data. A new model has now been developed by V. Truhlik and L. Triskova (Czech Rep), based on Atmosphere Explorer C,D,E, and Intercosmos 24 data. Comparisons with independent satellite data indicate a considerable improvement over the current IRI model. This new model will be implemented in the next version of the IRI.

Variability Model

Efforts are underway to establish a quantitative description of ionospheric variability for inclusion in the IRI. The IRI would then, in addition to the monthly mean, also provide a measure for the potential deviation from this mean (standard deviation, or quartiles). J. Minow (MSFC, USA) presented N_e and T_e variability models, based on a large amount of in-situ satellite measurements. The IRI Task Force Activity at ICTP has developed a first set of values using worldwide ionosonde data, and focusing on the variability of ionospheric-peak parameters. Two posters by M. Mosert (Argentina) et al. reviewed the variability of peak and profile parameters observed at several European and Argentine stations.

Data Sources

Data sources used included the IMAGE, ISIS, Alouette, Interkosmos 24, Picosat, Hinotori, ROCSAT-1, Akebono, Forte, CHAMP, and GPS satellites; the EISCAT, Millstone Hill, and Arecibo incoherent-scatter radars; new and old ionosonde measurements; and compilations of rocket data, and of data from older ionospheric satellites. An instrument with good potential for IRI work is the SCITRIS system, for monitoring total electron content and ionospheric scintillations. It is scheduled for launch on the STPSAT1 and NPSAT1 satellites in 2006 (P. Bernhardt, NRL, USA).

R. Moses (LANL, USA) explained how transionospheric RF signals from lightning can provide information about the electron content along the path, and discussed examples using FORTE satellite data. Occultation observations with GPS receivers on the Picosat and CHAMP satellites were discussed and evaluated by P. Straus (Aerospace Corp., USA) and N. Jakowski (Germany), respectively. The benefit of GPS observations for the IRI was highlighted by M. Hernandez-Pajares (Spain) and P. Wielgosz (Poland).

Miscellaneous

B. Reinisch was elected as new Chair of the IRI Working Group, and L. Triskova and M. Friedrich were chosen as URSI and COSPAR Vice Chairs, respectively. IRI activities will be coordinated with the help of the IRI Steering Committee (SC). In addition to the IRI Chair and Vice Chairs, the SC includes D. Bilitza and K. Rawer, who are former IRI Chairs and Editors of the IRI issues of *Advances in Space Research*; K.-I. Oyama, who is the Editor of the IRI *Newsletter*; and S. Radicella, who organizes and hosts the annual IRI Task Force Activity at the International Center for Theoretical Physics in Trieste, Italy. Of particular interest to IRI members are the ongoing activities at the International Standardization Organization (ISO) for registering an ISO standard model for the ionosphere. ISO had requested input from the IRI-WG regarding the current proposal, which is a modified IRI model that includes the Chasovitin-Gulyaeva plasmasphere and high-latitude models (SMI). The IRI group noted that there are now a number of good plasmasphere models, and an overall evaluation is needed to determine which model should be included with the IRI. In the meantime, the IRI-WG recommended that the current ISO proposal be modified to only include the ionosphere, and to only include the IRI-2000 model. It is also important to resolve potential copyright issues with ISO, because it is essential that the IRI remains an open and freely available model.

Dieter Bilitza
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EMF and Cardiac Pacemakers Defibrillators

Paris, France, 25 October 2002

The Non-Ionizing Radiation Section of the French Radioprotection Society (SFRP) and the Cardiac Stimulation Group of the French Cardiology Society (SFC) organized a scientific workshop : « Electromagnetic Fields, Cardiac Pacemakers and Defibrillators », Friday October 25, 2002 in the buildings of the Union Internationale des Chemins de Fer in Paris.

This workshop aimed to present the state of scientific, normative, and medical knowledge on the various situations involving interactions between electromagnetic fields (ELF and radio frequencies) and cardiac pacemakers and defibrillators ; to inform the medical community in order to improve communications on the subject ; to make industry alive to the need for good information ; and to contribute to the information of patients who carry these systems.

More than one hundred of people attended the meeting, coming from different horizons : cardiologists, occupational physicians, representatives of manufacturers of implants, "producers of waves", ministries and government agencies, European Community.

Interventions, varied and covering all the fields from the medical to physical aspects, were of great quality. Dr. Anne Chérin animated the workshop and directed the debates during the three sessions and the round table.

In introduction, Pr Joussot-Dubien, president of Non-Ionizing Radiation Section of the SFRP recalled the objectives of the Association, and Pr Djiane, president of the Cardiac Stimulation Group of the SFC, reviewed the main themes of the workshop. It emerges from of this workshop that in the large majority of the cases the level of magnetic and electric fields is much lower than that suitable for affect the implants.

During the first session, chaired by Pr Joussot-Dubien, Mr. Guiguet, of the ANFR (National Agency of the Frequencies) presented the electromagnetic sources of the various radioelectric stations of the different radiocommunication services in the environment, as well as the results of a series of electromagnetic fields measurements at the close vicinity of various types of stations. Dr. Dodinot (Department of cardiology, CHU Nancy) then made the history of the electromagnetic disturbances of cardiac implantable pacemakers and defibrillators, as well as the point in 2002, whatever the sources, thus giving us the point of view of the clinicians. Pr Nadi (University Henri Poincaré, Nancy) presented the interest of in vitro studies to characterize the immunity of the cardiac implants, with the results of its work at low frequency (50 and 60 Hz) and at induction frequencies (10 and 25 kHz). Pr Silny (Aachen University Hospital, Germany) closed this first session by presenting the German experience of the interferences between pacemakers and low frequencies.

During the second session, chaired by Pr Djiane, Dr. Frank presented the results of a study with volunteers implanted with recent pacemaker, subjected to a field of 50 or 60 Hz, 50 μT and during culinary handling with an induction cooktop (20 to 50 kHz). Dr. Trigano studied as for him the interferences between the cardiac implants (pace and défibrillators) and the radio frequencies, electronic article survey devices and other sources of radio frequencies, in particular in medical environment. He then handed over to Dr. Frank again who evoked, without being able to solve them completely, the questions related to nuclear magnetic resonance imagery for wearers of cardiac pacemakers or defibrillators.

The last session, chaired by Pr Miro, was devoted to standardization and problems encountered in professional environment where the exposure levels are higher. Mr. Burais (CEGELY, Central School of Lyon) presented the normative aspect of the external sources of electromagnetic fields and the examples of modeling the phenomena related to these fields in the human body. Mr. Andrivet (Trade association of the manufacturers of implants) then presented the various standards relating to the implantable medical devices elaborate by the experts and make use of by the manufacturers. Finally Dr. de Sèze of INERIS (National Institute of the industrial environment and the risks) evoked various situations of possible interferences in work environment : welding, cooking by induction, etc

The workshop ended in a debate between the room and the speakers which allowed everybody to get answers adapted to its interrogations.

The proceedings of this workshop will be published soon. Contact Dr. Souques : Tel. : 01 55 31 46 06, fax : 01 55 31 46 20, email: martine.souques@edfgdf.fr. Meanwhile, abstracts are on line : http://www.sfrp.asso.fr/

Dr Martine Souques

CONFERENCE ANNOUNCEMENT

Spatio-Temporal Analysis and Multipoint Measurement in Space - STAMMS

Orleans, France, 12 - 16 May 2003

Objective

A conference-workshop on "Spatio-Temporal Analysis and Multipoint Measurements in Space" will be held in Orléans (France) from 12 to 16 of May 2003.

The main objective of the conference is to review the first results of the CLUSTER project, in particular those results that have improved our understanding of fundamental questions in solar-terrestrial and magnetospheric physics.

The CLUSTER mission is the first one to provide four-point measurements that allow to distinguish spatial and temporal variations in space plasmas. Such a multi-point formation is crucial for studying non-stationary multiscale phenomena prevailing in magnetospheric boundary regions (bow-shock, magnetopause, boundary layers, cusp, auroral field lines, neutral sheet...). The analysis of the first CLUSTER data has already provided a wealth of novel informationabout the basic physical processes at play within these key regions (shock formation, magnetic reconnection, turbulence, substorm initiation processes...).

The meeting will be organised as a series of topical sessions focusing upon critical regions in the magnetosphere and critical unsolved problems. Simulation results relevant to each topical session and results from other multi-satellite missions will provide valuable inputs to the discussions. A session will be dedicated to the correlated CLUSTER and ground based observations. Perspectives for future multi-satellite missions will also be discussed.

Scientific committee / Comité scientifique

H. Alleyne, M. André, S. Bale, A. Balogh, J.-L. Bougeret, P. Cargill, N. Cornilleau-Wehrlin, P. Daly, P. Décréau, T. Dudok de Wit, M. Dunlop P. Escoubet, A. Fazakerley, H. de Feraudy, A. Galeev, M. Goldstein, C. Hanuise, U. Inan, P. Kintner, V. Krasnoselskikh, F. Lefeuvre, D. Le Quéau E. Moebius, G. Paschmann, J. Pickett, H. Reme, A. Roux, J.-A. Sauvaud, M. Scholer, S. Schwartz, D. Southwood, L. Zelenyi

Organisers / Organisateurs

Vladimir Krasnoselskikh, Pierrette Décréau, Thierry Dudok de Wit, LPCE/CNRS-Université d'Orléans, France and Philippe Escoubet, ESTEC/ESA, AG Noordwijk, Netherlands

Local committee / Comité local

Pierrette Décréau, Thierry Dudok de Wit, Paul Gille, Vladimir Krasnoselskikh, Bertrand Lefebvre, Jean-Louis Pinçon

Contact

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http://web.cnrs-orleans.fr/~weblpce/stamms/

9th International Symposium on Microwave & Optical Technology - ISMOT'03

Ostrava, Czech Republic, 11 - 15 August 2003

Topics

- RF
- micro&millimeter-wave components and systems
- solid state devices
- antenna and radar technologies
- MICs/MMICs
- remote sensing
- biological effects and applications
- communications systems
- numerical methods and CAD techniques
- propagation /scattering and measurements
- electro-optics, optical fibers and waveguides
- optical solitons
- optical communications/networks and sensors
- laser technology
- optical multiplexing/demultiplexing
- microwave superconductivity applications
- industry and environmental effects
- signal processing
- microwave photonics
- microwave materials
- MEMS
- nanotechnology
- optics
- electromagnetic field education

Symposium Chair & Co-Chair

Conference Chair : Prof. Jaromír Pištora, Technical University of Ostrava, Czech Republic
Co-Chair : Prof. Banmali S. Rawat, University of Nevada, USA.

Submission Deadlines

Abstracts: April 15, 2003
Papers: August 15, 2003
Registration: June 30, 2003.

Contact

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CZECH REPUBLIC
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Event URL: http://www.ismot2003.cz/
Event E-mail: ismot2003@vsb.cz

Asia-Pacific Microwave Conference APMC 2003

Seoul, Korea, 4 - 7 November 2003

The 2003 Asia-Pacific Microwave Conference (APMC '03) will be held in Seoul, Korea, from 4 to 7 November 2003. This conference is organized by the Korea Electromagnetic Engineering Society (KEES) and Ministry of Information & Communication (MIC), is sponsored by the Korean Institute of Communication and Sciences (KICS) and Radio Education Research Center (RERC), and is technical co-sponsored by IEEE MTT/AP/EMC Korea Chapters and Union Radio-Scientifique Internationale (URSI) Committee in South Korea.

Conference chairs & Vice-Chairs

General Chair: Prof. Hyuck Jae Lee, ICU
Honorary Chair: Prof. Jung-Woong Ra, K-JIST
Vice Chairs: Prof. Dong Chul Park, Chungnam National University & Prof. Dong Il Kim, Korea Maritime University

Topics

Areas of interest include, but are not limited to: 1. Solid state Devices and Circuits, 2. Low-noise Devices and Techniques, 3. High-power Devices and Techniques, 4. Monolithic Integrated Circuits, 5. Passive Devices and Circuits, 6. Packaging Techniques, 7. Ferrite and SAW Components, 8. Microwave Superconductivity, 9. Microwave-optical Design, 10. Computer Aided Design, 11. Measurement Techniques, 12. Electromagnetic Field Theory, 13. Computational Electromagnetics, 14. Microwave Antennas, 15. Phased and Active Array Techniques, 16. Scattering and Propagation, 17. Microwave Remote Sensing and Sensors, 18. Microwave and Millimeter Wave Systems, 19. Communication Systems, 20. High Speed Digital Circuits, 21. Medical and Biological Applications, 22. Submillimeter Wave Techniques, 23. EMI and EMC, 24. Photonics and Optics, 25. Wireless RF Components and Systems, 26. Any other relevant topics

Deadlines

Paper Submission Deadline: April 30, 2003
Notification of Acceptance: June 15, 2003
Final Paper Delivery: August 15, 2003

Contact

APMC '03 Secretariat (Conference office)
GENICOM Convention Service Co.
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E-mail : apmc@icu.ac.kr
Web: http://www.apmc2003.org/~apmc

ClimDiff'03

Fortaleza, Brazil, 17 - 19 November 2003

General

A three-day specialist colloquium/workshop meeting is planned on the same basis as the Climpara meetings held in Moscow (1994), Oslo (1996), Ottawa (1998) and Budapest (2001), for which the forerunner established "the spirit of Rio" in Rio de Janeiro (1990). But this time there is a particular Difference, namely to incorporate aspects of Diffraction (see below). This URSI Commission F meeting would again immediately precede parallel meetings of ITU Working Parties, this time WPs 3J (Radiowave propagation fundamentals), 3K (Radiowave point-to-area propagation predictions) and 3M (Radiowave point-to-point propagation predictions) on 20-28 November 2003. Participants in the URSI aspects would be encouraged to stay for (at least some of) the ITU-R aspects as members of their country's delegation, and vice versa.

Topics

The meeting is scheduled to be in two parts:

- The "Clim" part (traditionally on *the use of climatic parameters in the prediction of radiowave propagation characteristics*) is expected to benefit from some significant new activities, and is intended to cover (i) clear air modelling and climatic parameters needed, data available, measurements still needed and instruments, and (ii) precipitation modelling and climatic parameters needed, data available, measurements still needed and instruments. In both cases mapping processes will be very relevant.
- The "Diff" part is expected to include (i) hill tops and hairy hill tops, (ii) propagation over, between and through buildings and vegetation, (iii) ray tracing, parabolic equation and integral equation, and (iv) derivation and application of high-resolution topographic and land-use maps, and 3-D-city maps. It could also include area coverage modelling and results, vegetation effects, new techniques and data sources, and indoor, short-range and building penetration.

Abstracts

Copies of synopses for contributions should be emailed attachments to be received BEFORE 2 JUNE 2003 at the address below. They should print as no more that one sheet of A4 paper, but give sufficient information to enable an objective assessment to be made by referees. As well as title of paper, name(s) of author(s), name(s) of organisation(s), email address(es), phone and fax number(s), and full postal address(es), Refereeing Abstracts should opt for Oral/ Poster presentation and should indicate the appropriate topic, as indicated above. The meeting and papers will be in English.

Contact

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Email: Martin.Hall@rl.ac.UK
See also http://www.climdiff.com

URSI CONFERENCE CALENDAR

February 2003

EMC Zurich '03 - 15th International Zurich Symposium and Technical Exhibition on Electromagnetic Compatibility
Zurich, Switzerland, 18-20 February 2003
Contact : Dr. G. Meyer, Chairman EMC Zurich, ETH Zentrum - IKT, CH-8092 Zurich, Switzerland, Tel. +411-632-2790, fax +411-632-1209, gmeyer@nari.ee.ethz.ch , http://www.emc-zurich.ch/emc03/

April 2003

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

May 2003

STAMMS - Spatio-Temporal Analysis and Multipoint Measurement in Space
Orleans, France, 12 - 16 May 2003
Contact: LPCE/CNRS and Université d'Orléans, 3A av. de la Recherche Scientifique, F-45071 Orléans, France, Fax: +33 238 63 12 34, http://web.cnrs-orleans.fr/~weblpce/stamms/

MST 10 - Tenth International Workshop on Technical and Scientific Aspects of MST Radar
Piura, Peru, 20-27 May 2003
Contact : Dr. Jürgen Röttger, Max-Planck-Institut fûr Astronomie, D-37191 Katlenburg-Lindau, Germany, Fax +49 5556-979 410, E-mail roettger@linmpi.mpg.de, http://jro.igp.gob.pe (conference site not yet installed)

August 2003

ISMOT 2003 - 9th International Symposium on Microwave and Optical Technology
Ostrava, Czech Republic, 11-15 August 2003
Contact: Prof. Jaromír Pištora, Symposium Chair, Department of Physics, Technical University of Ostrava, 708 33 Ostrava - Poruba, Czech Republic, E-mail: ismot2003@vsb.cz , http://www.ismot2003.cz

October 2003

Telecom 2003 & JFMMA
Marrakech, Morocco, 15-17 October 2003
Contact : Prof. Ahmed Mamouni, IEMN, Cité Scientifique, Av. Poincaré, B.P. 69, F-59652 Villeneuve d'Ascq, France, Fax +33 320197880, E-mail : ahmed.mamouni@iemn.univ-lille1.fr

November 2003

APMC 2003
Seoul, Korea, 4-7 November 2003
Contact : Prof. Hyo Joon Eom, Dept. of Electrical Engineering, Korea Advanced Institute of Science and Technology, 373-1, Kusong-dong, Yusong-gu, Taejon, Korea, Fax : +82 42-869 8036, hjeom@ee.kaist.ac.kr , http://www.apmc2003.org

CLIMDIFF'03
Fortaleza, Brazil, 17-19 November 2003
Contact: Martin P M Hall, ClimDiff'03, RCRU, Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX, UK, Fax: +44 1235 446140, Email: Martin.Hall@rl.ac.uk, http:// www.climdiff.com

May 2004

2004 International Symposium on Electromagnetic Theory
Pisa, Italy, 23-27 May 2004
Contact : Prof. Makoto Ando, Dept. of Electrical and Electronic Engineering, Tokyo Institute of Technology, 2-12-1, Ohokayama, Meguro, Tokyo 152-8552, Japan, E-mail: mando@antenna.ee.titech.ac.jp or Prof. Lotfollah Shafai, Dept. of Electrical & Computer Eng., University of Manitoba, 15 Gillson Street, Winnipeg, MB R3T 5V6, Canada, E-mail: shafai@ee.umanitoba.ca

August 2004

ISAP'04 - 2004 Intermediate Int. Symp. on Antennas and Propagation
Sendai, Japan, 17-21 August 2004
Contact : ISAP'04, Attn. Dr. Tokio Taga, NTT DoCoMo, Inc., 3-5, Hikarino-oka, Yokosuka, 239-8536 Japan, E-mail : isap-2004@mail.ieice.org , http://www.ieice.org/cs/isap/2004

An up-to-date version of this Conference Calendar, with links to the various conference web sites can be found at http://www.ursi.org/Calendar.html

Do you wish to announce your meeting in this Calendar? More information about URSI-sponsored meetings can be found on our Homepage at : http://www.ursi.org/Rules.html

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

News from the URSI Community

NEWS FROM COMMISSION B

2004 International Electromagnetics Prize

URSI Commission B with the approval of the URSI Board of Officers has established the International Electromagnetics Prize to be awarded annually. The prize is $10,000 US plus a commemorative plaque and is sponsored by the Summa Foundation. It is awarded for an accurate approximate solution of a designated scattering or related problem in electromagnetics and is presented at an appropriate URSI meeting. The first prize will be awarded in Spring 2003.

General Information

The last 30 years have seen enormous advances in the application of numerical techniques in electromagnetics, but there have not been comparable advances in our knowledge of the scattering from simple geometric shapes. It is hoped that the prize will encourage the development of accurate physically-based approximate analytical expressions for the solution of canonical and similar problems.

On 15 September of each year the designated problem will be announced on the URSI web page (http://www.ursi.org) and elsewhere.

Solutions are due by 15 January, 16 months after the announcement date. Entries must be in English in the format of a paper submission to the journal Radio Science and not exceed 25 pages in length, including tables, figures and references. Hard copy or electronic submission is acceptable. Entries will be judged by a panel appointed by the chair of URSI Commission B and the Summa Foundation. Factors taken into account in the judging will be the simplicity and elegance of the expressions, their conformity with the known physical properties of the solution, and their accuracy for all values of the parameters involved in the problem. The winner will be announced on 15 April of the year of submission. There is the right to withhold the award if, in the opinion of the panel, no worthy entry is received.

All scientists are eligible for the prize apart from an officer or director of the Summa Foundation, a member of the panel, or one of their immediate working associates.

Since the prize is awarded for the best paper submitted. Multiple authorship is allowed.

Topic

The topic is the scattering of a uniform plane wave by an infinitesimally thin, perfectly conducting quarter plane occupying the portion $|y| < x, x> 0$ of the plane $z = 0$ in Cartesian coordinates. The quarter plane resides in homogeneous space of infinite extent characterized by (μ, e).

Using, for example, an analytical method such as an eigenfunction expansion in terms of Lamé functions or a two-dimensional Wiener-Hopftechnique, or a numerical method in either the time or frequency domain (with the structure appropriately terminated in the latter case), one might wish to determine the scattering matrix for either time harmonic or general time dependant excitation. The data so obtained should be used to develop accurate physically-based analytical expressions for the scattered field accompanied by conditions indicating the range of validity and an inclusive specification of the accuracy.

A minimally acceptable solution might be one for which either the incident or scattered wave (but not both) is in the xz plane. Contestants are encouraged to submit a solution which is as general as feasible for which the accuracy is specified. A solution whose specified range of validity is limited but whose accuracy is tightly bounded will be looked upon more favorably than one which holds over a greater range but whose accuracy is not proved or tightly bound.

Submission

The members of the panel are C.M. Butler (Chair), C.E. Baum, K.J. Langenberg, T.B.A. Senior and S. Ström. Entries in the format described above must be received prior to **15 January 2004** by :

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336 Fluor Daniel EIB
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BOOK PUBLISHED BY AN URSI RADIOSCIENTIST

The High Latitude Ionosphere and its effects on Radio Propagation

by R. D. Hunsucker and J. K. Hargreaves

The physical properties of the ionized layer in the Earth's upper atmosphere enable us to use it to support an increasing range of communications applications. This book presents a modern treatment of the physics and phenomena of the high latitude upper atmosphere and the morphology of radio propagation in the auroral and polar regions. Chapters cover the basics of radio propagation and the use of radio techniques in ionospheric studies. Many investigations of high-latitude radio propagation have previously only been published in conference proceedings and organizational reports. This book includes many examples of the behavior of quiet and disturbed high-latitude HF propagation. Ample cross-referencing, chapter summaries, and reference lists make this book an invaluable aid for graduate students, ionospheric physicists, and radio engineers.

Contents

2003, 617 pp., Cambridge University Press, ISBN 0 521 33083 1. This is part of the Cambridge Atmospheric and Space Science Series.

URSI Website

For the latest news from URSI, please visit:

http://www.ursi.org/Latest.html

International Geophysical Calendar 2003

U.R.S.I.

	S	M	T	W	T	F	S
JANUARY				1*	2*N	3	4
	5	6	7	8	9	10	11
	12	13	14	15	16	17	18F
	19	20	21	22	23	24	25
	26	27	28	29*	30*	31	1N
FEBRUARY	2	3	4	5	6	7	8
	9	10	11	12	13	14	15
	16F	17	18	19	20	21	22
	23	24	25	26*	27*	28	1
MARCH	2	3N	4	5	6	7	8
	9	10	11	12	13	14	15
	16	17	18F	19	20	21	22
	23	24+	25+	26*+	27*+	28+	29
	30	31	1N	2	3	4	5
APRIL	6	7	8	9	10	11	12
	13	14	15	16F	17	18	19
	20	21	22	23*	24*	25	26
	27	28	29	30	1N	2	3
MAY	4	5	6	7	8	9	10
	11	12	13	14	15	16F	17
	18	19	20	21	22	23	24
	25	26	27+	28*+	29*+	30	31N
JUNE	1	2	3	4	5	6	7
	8	9	10	11	12	13	14F
	15	16	17	18	19	20	21
	22	23	24+	25*+	26*+	27	28
	29N	30					
	S	M	T	W	T	F	S

S	M	T	W	T	F	S	
		1	2	3	4	5	JULY
6	7	8	9	10	11	12	
13F	14	15	16	17	18	19	
20	21	22	23*	24*	25	26	
27	28	29N	30	31	1	2	
3	4	5	6	7	8	9	AUGUST
10	11	12F	13	14	15	16	
17	18	19	20	21	22	23	
24	25	26*	27*N	28	29	30	
31	1	2	3	4	5	6	SEPTEMBER
7	8	9	10F	11	12	13	
14	15	16	17	18	19	20	
21	22+	23+	24*+	25*+	26N+	27	
28	29	30	1	2	3	4	OCTOBER
5	6	7	8	9	10F	11	
12	13	14	15	16	17	18	
19	20	21+	22*+	23*+	24	25N	
26	27	28	29	30	31	1	
2	3	4	5	6	7	8	NOVEMBER
9F	10	11+	12+	13+	14+	15+	
16+	17	18	19*	20*	21	22	
23N	24	25	26	27	28	29	
30	1	2	3	4	5	6	DECEMBER
7	8F	9	10	11	12	13	
14	15	16+	17+	18+	19	20	
21	22	23*N	24*	25	26	27	
28	29	30	31	1	2	3	2004
4	5	6	7F	8	9	10	JANUARY
11	12	13	14	15	16	17	
18	19	20*	21*N	22	23	24	
25	26	27	28	29	30	31	
S	M	T	W	T	F	S	

N NEW MOON F FULL MOON

- (21) Regular World Day (RWD)
- (22) Priority Regular World Day (PRWD)
- [19] Quarterly World Day (QWD) also a PRWD and RWD
- 1 Regular Geophysical Day (RGD)
- [10 11] World Geophysical Interval (WGI)
- + Incoherent Scatter Coordinated Observation Day
- [31] Day of Solar Eclipse: May 31 and Nov 23-24
- [2 3] Airglow and Aurora Period
- 1* Dark Moon Geophysical Day (DMGD)

This Calendar continues the series begun for the IGY years 1957-58, and is issued annually to recommend dates for solar and geophysical observations, which cannot be carried out continuously. Thus, the amount of observational data in existence tends to be larger on Calendar days. The recommendations on data reduction and especially the flow of data to World Data Centers (WDCs) in many instances emphasize Calendar days. The Calendar is prepared by the International Space Environment Service (ISES) with the advice of spokesmen for the various scientific disciplines.

The **Solar Eclipses** are:

- **31 May 2003 (annular) eclipse** with annularity visible from northernmost Scotland (including Orkney, Shetland, and the Hebrides), the Faroe Islands (Denmark), Jan Mayen Island (Norway), Iceland, and mid-Greenland. Partial phases visible in NE Africa, in Europe (including the British Isles) except the Iberian Peninsula, extreme NE Canada, Alaska, and a broad swath of northern Asia. Annularity has 0.938 eclipse magnitude, and lasts as long as 3minutes 37 seconds in Greenland. See www.eclipses.info.
- **23-24 November 2003 (total) eclipse** with totality visible only from parts of Antarctica and Southern Ocean nearest Perth. Partial eclipse visible in Australia and New Zealand (except their northern parts), Antarctica, S. Pacific Ocean, the Southern Ocean, and southern tip of S. America. Total eclipse magnitude is 1.038 in Antarctica with maximum duration 1m 57s. See http://sunearth.gsfc.nasa.gov/eclipse/SEplot/SEplot2001/SE2003Nov23T.gif. (Description by Dr. Jay Pasachoff, Williams College, Chair of IAU WG on Solar Eclipses, jmp@williams.edu based on maps from Fred Espenak, NASA GSFC. See http://sunearth.gsfc.nasa.gov/eclipse/SEcat/SEdecade2001.html and www.williams.edu/Astronomy/IAU_eclipses. See also International Astronomical Union Program Group on Public education at the times of Eclipses: http://www.eclipses.info

Meteor Showers (selected by R. Hawkes, Mount Allison Univ, Canada, rhawkes@mta.ca) include important visual showers and also unusual showers observable mainly by radio and radar techniques. The dates are given in Note 1 under the Calendar.

Definitions:

Time = Universal Time (**UT**);

Regular Geophysical Days (**RGD**) = each Wednesday;

Regular World Days (**RWD**) = Tuesday, Wednesday and Thursday near the middle of the month (see calendar);

Priority Regular World Days (**PRWD**) = the Wednesday **RWD**;

Quarterly World Days (**QWD**) = **PRWD** in the **WGI**;

World Geophysical Intervals (**WGI**) = 14 consecutive days each season (See calendar);

ALERTS = occurrence of unusual solar or geophysical conditions, broadcast once daily soon after 0400 UT;

STRATWARM = stratospheric warmings

Retrospective World Intervals (**RWI**) = MONSEE study intervals.

For more detailed explanations of the definitions, please see one of the following or contact H. Coffey (address below): ISES Synoptic Codes for Solar and Geophysical Data; Solar-Geophysical Data, October issue; URSI Information Bulletin; COSPAR Information Bulletin; IAGA News; IUGG Chronicle; WMO Bulletin; IAU Information Bulletin; and the Journal of Atmospheric and Terrestrial Physics (UK). WWW homepage **http://ises-spaceweather.org.**

PRIORITY RECOMMENDED PROGRAMS FOR MEASUREMENTS NOT MADE CONTINUOUSLY (in addition to unusual ALERT periods):

Aurora and Airglow. Observation periods are New Moon periods, especially the 7 day intervals on the calendar;

Atmospheric Electricity. Observation periods are the RGD each Wednesday beginning on 1 January 2003 at 0000 UT, 8 January at 0600 UT, 15 January at 1200 UT, 22 January at 1800 UT, etc. Minimum program is PRWDs.

Geomagnetic Phenomena. At minimum, need observation periods and data reduction on RWDs and during MAGSTORM Alerts.

Ionospheric Phenomena. Quarter-hourly ionograms; more frequently on RWDs, particularly at high latitude sites; ionogram scaled parameters to WDCs; continuous observations for solar eclipse in the eclipse zone. See Airglow and Aurora.

Incoherent Scatter. Observations on Incoherent Scatter Coordinated Days; also intensive series on **WGIs** or **Airglow and Aurora** periods.

Special programs. Dr. A. P. van Eyken, EISCAT Scientific Assoc., Ramfjordmoen, N-9027 Ramfjordbotn, Norway. Tel. +47 77692166; Fax +47 77692380 , e-mail tony@eiscat.no, URSI Working Group G.5. See www.eiscat.uit.no/URSI_ISWG.

Ionospheric Drifts. During weeks with RWDs.

Traveling Ionosphere Disturbances. Special periods, probably PRWD or RWDs.

Ionospheric Absorption. Half-hourly on RWDs; continuous on solar eclipse days for stations in eclipse zone and conjugate area. Daily measurements during Absorption Winter Anomaly at temperate latitude stations (Oct-Mar Northern Hemisphere; Apr-Sep Southern Hemisphere).

Backscatter and Forward Scatter. RWDs at least.

Mesospheric D region electron densities. RGD around noon.

ELF Noise Measurements of earth-ionosphere cavity resonances WGIs.

All Programs. Appropriate intensive observations during unusual meteor activity.

Meteorology. Especially on RGDs. On WGIs and STRATWARM Alert Intervals, please monitor on Mondays and Fridays as well as Wednesdays.

GAW (Global Atmosphere Watch) -- WMO program to integrate monitoring of atmospheric composition. Early warning system of changes in atmospheric concentrations of greenhouse gases, ozone, and pollutants (acid rain and dust particles). WMO, 7 via avenue de la Paix, P.O. Box 2300, 1211 Geneva, Switzerland.

Solar Phenomena. Solar eclipse days, RWDs, and during PROTON/FLARE ALERTS.

ISCS (International Solar Cycle Studies) 1998-2002(3) SCOSTEP project. observations and analyses of underlying and resulting processes associated with the rising and maximum phase of the solar cycle. Contacts: S.T. Wu, Univ of Alabama, Huntsville Dept. Mech. Eng. & Ctr. for Space Plasma & Aeron. Res., Huntsville, AL 35899 USA, (205)895-6413, Fax (205)895-6328, wu@cspar.uah.edu and V. Obridko, IZMIRAN, Solar Physics Dept, 142092 Troitsk, Moscow, Russia. Tel 095-334-0926; Fax 095-344-0124, obridko@lars.izmiran.troitsk.su.

S-RAMP (STEP [Solar Terrestrial Energy Program] Results, Applications, and Modeling Phase) - - Global coordinated ground-based and space-borne observations of space weather phenomena covering the entire space weather chain from the surface of the Sun to the effects on the near-Earth space and ground-based technological systems. Contacts: Dr. David Boteler (boteler@geolab.nrcan.gc.ca) and Dr. Phil Wilkinson (phil@ips.gov.au). See www.ngdc.noaa.gov/stp/SRAMP/sramp.html.

Space Research, Interplanetary Phenomena, Cosmic Rays, Aeronomy. QWDs, RWD, and Airglow and Aurora periods.

The **International Space Environment Service (ISES)** is a permanent scientific service of the International Union of Radio Science (URSI), with the participation of the International Astronomical Union and the International Union Geodesy and Geophysics. ISES adheres to the Federation of Astronomical and Geophysical Data Analysis Services (FAGS) of the International Council for Science (ICSU). The ISES coordinates the international aspects of the world days program and rapid data interchange.

This Calendar for 2003 has been drawn up by H.E. Coffey, of the ISES Steering Committee, in association with spokesmen for the various scientific disciplines in SCOSTEP, IAGA and URSI. Similar Calendars have been issued annually beginning with the IGY, 1957-58, and have been published in various widely available scientific publications. PDF versions are available online (ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/IGC_CALENDAR).

Published for the International Council for Science and with financial assistance of UNESCO.

Additional copies are available upon request to ISES Chairman, Dr. David Boteler, Geological Survey of Canada National Geomagnetism Program, #7 Observatory Crescent, Ottawa, Ontario, Canada, K1A 0Y3 FAX (613) 824-9803, e-mail Boteler@geolab.NRCan.gc.ca, or ISES Secretary for World Days, Ms. H.E. Coffey, WDC-A for Solar-Terrestrial Physics, NOAA, E/GC2, 325 Broadway, Boulder, Colorado 80305, USA, FAX (303)497-6513, e-mail Helen.E.Coffey@noaa.gov.

The calendar is available on-line at **http://ises-spaceweather.org.**

NOTES on other dates and programs of interest:

1. Days with **significant meteor shower activity** are: Northern Hemisphere 4 Jan; 21-23 Apr; 4-6 May; 6-11, 27-29 Jun; 12-14 Aug; 21-23 Oct; 18-19 Nov; 13-15, 22-23 Dec 2003; 4 Jan 2004. Southern Hemisphere 4-6 May; 6-11, 27-29 Jun; 27 Jul-2 Aug; 21-23 Oct; 18-19 Nov; 13-15 Dec 2003. These can be studied for their own geophysical effects or may be "geophysical noise" to other experiments.
2. **Global Atmosphere Watch (GAW)** — early warning system for changes in greenhouse gases, ozone layer, and long range transport of pollutants. (See Explanations.)
3. **ISCS (International Solar Cycle Studies)** Observing Program 1998-2002: SCOSTEP Study of processes associated with the maximum phase of the solar cycle. (See Explanations.)
4. **S-RAMP — SCOSTEP Project.** Solar Terrestrial Energy Program (S) - Results, Applications, and Modeling Phase (RAMP). (See Explanations.)
5. **+ Incoherent Scatter Coordinated Observations Days** (see Explanations) starting at 1300 UT on the first day of the intervals indicated, and ending at 1600 UT on the last day of the intervals: 3-28 Mar Storms/TIMED/LTCS alert interval (24-28 Mar default); 27-29 May Low/High latitude; 24-26 Jun Database: F-region/wide coverage; 1-26 Sep Storms/TIMED/LTCS alert interval (22-26 Sep default); 21-23 Oct High Altitude; 11-16 Nov LTCS; 16-18 Dec Low/High latitude — see http://www.eiscat.uit.no/URSI_ISWG/2003_schedule.html, where

   Database = Emphasis on broad latitutdinal coverage of the F region (Tony van Eyken - Tony.van.Eyken@eiscat.com);

   LTCS = Lower Thermosphere Coupling Study (C. Fessen - fesen@tides.utdallas.edu);

   TIMED = Thermosphere Ionosphere Mesosphere Energetics Dynamics satellite (Joe Salah - jsalah@haystack.mit.edu).

URSI Publications

Modern Radio Science 1999

Editor: Maria Stuchly
ISBN 0-7803-6002-8
List Price : USD 49.95 Member Price : USD 45.00
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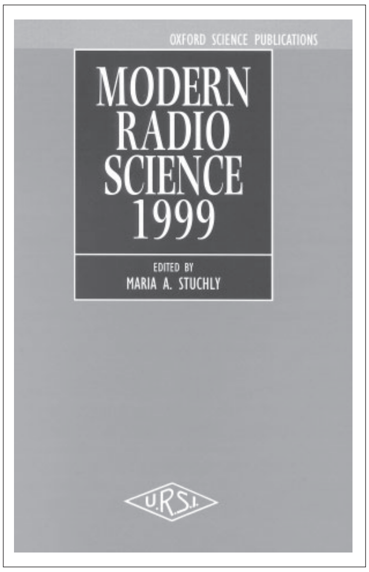

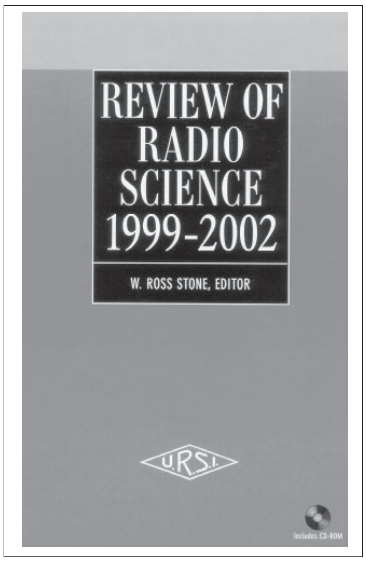

Review of Radio Science 1999-2002

Editor: W. Ross Stone
July 2002/Hardcover/977 pp
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List Price : USD 125.00 Member Price : USD 106.25
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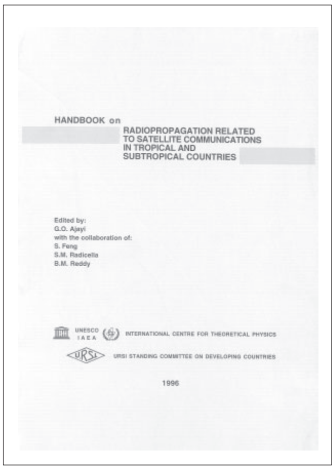

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Editor-in-Chief:
T.L. Killeen, National Centre for Atmospheric Research, Boulder, Colorado, 80307 USA

Editorial Office:
P.O. Box 1930, 1000 BX Amsterdam, The Netherlands

Special Rate for URSI Radioscientists 2003:
Euro 149.00 (US$ 149.00)
Subscription Information
2002: Volume 65 (18 issues)
Subscription price: Euro 2659 (US$ 2975)
ISSN: 1364-6826

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