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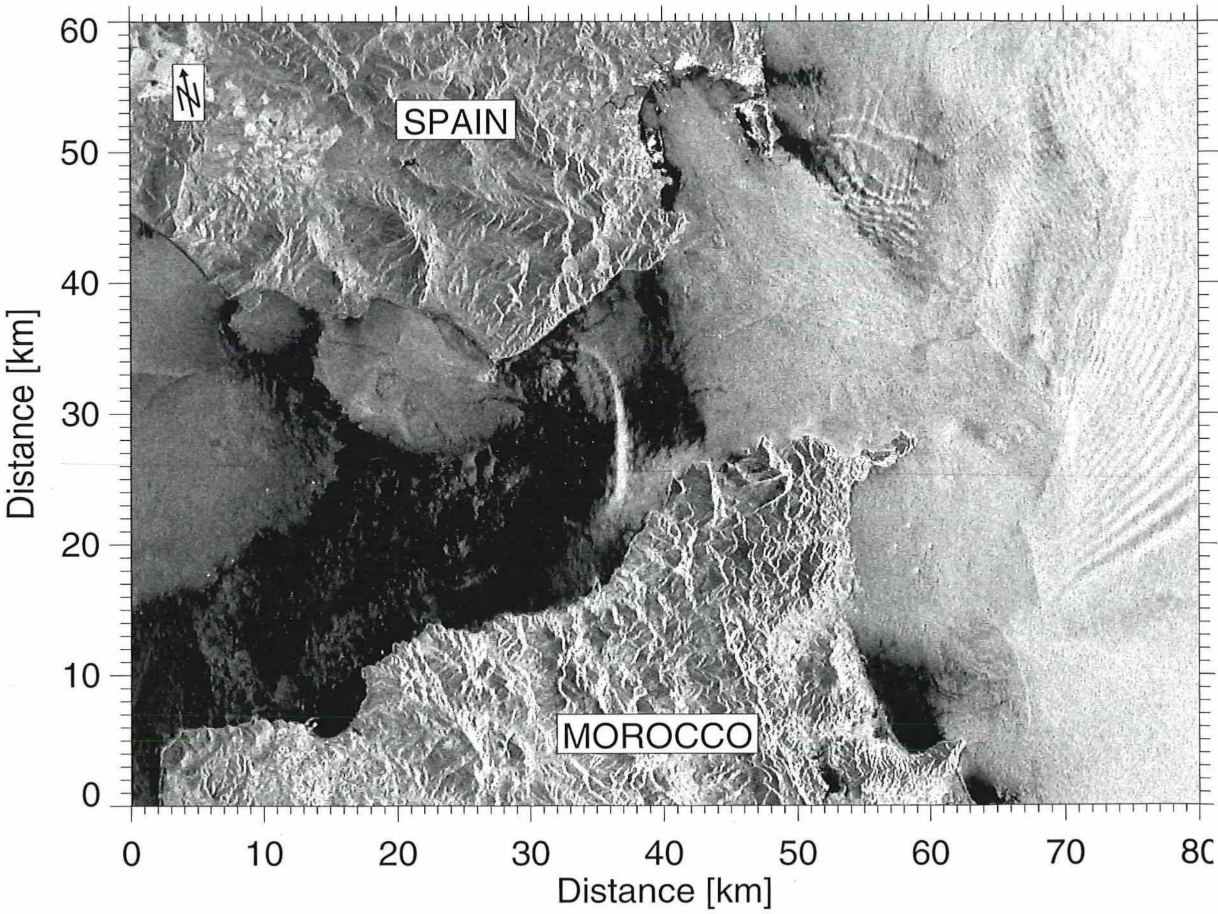

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Front cover: Section of an ERS-1 SAR image of the Strait of Gibraltar acquired on Jan. 20, 1994, at 11:03 UTC (orbit 13151, frames 2871/2889). It shows sea surface expressions associated with an internal soliton in the Strait (bended bright line) and an internal wave packet east of the Strait which was generated during the previous tidal cycle. (More on pp. 14-22)

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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

Dear URSI Correspondent,
Our Union is one of these very few places where fundamental and applied science can meet in a common home. The three articles published in this issue of the Bulletin are a good illustration of this.

Instruments and techniques of the kind described by Prof. Alpers will play a key role in monitoring the state of our planet and particularly the polluting influence of human activity. Mobile radio communications presently know an explosive development which is not likely to decrease in the future. Prof. Stuchly's paper investigates the quite difficult problem of resulting bioelectromagnetic effects on the human being. The paper prepared by your editor in close collaboration with an industrial partner was written in answer to concerns expressed by the radioastronomy community on spectrum pollution by satellites using spread spectrum techniques.

A common concern of these papers is our global environment. I hope that you will enjoy these contributions, which illustrate one of the most interesting characteristics of URSI : interdisciplinarity.

P. Delogne, Editor.

URSI on the Web

The URSI Homepage is now maintained by the URSI Secretariat. Feel free to download from the World Wide Web all you want to know about URSI.
Our URL is :

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We have received contributions from Commission G, other Commissions are hereby invited to send in their information.
Please send all remarks and contributions to :
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The object of the International Union of Radio Science (Union Radio-Scientifique Internationale) is to stimulate and to coordinate, on an international basis, studies in the field of radio, telecommunication and electronic sciences and, within these fields:

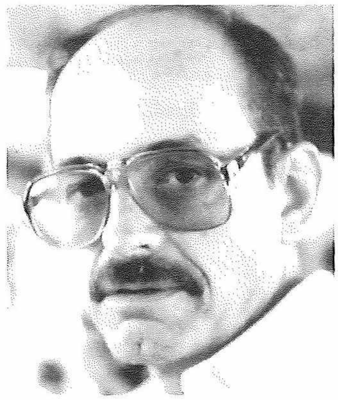
a) to promote and organise research requiring international cooperation, and the discussion and dissemination of the results of this research ;
b) to encourage the adoption of common methods of measurement, and the intercomparison and standardisation of the measuring instruments used in scientific work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

In Memoriam

Arthur Donald (Don) Spaulding

1935 - 1995

The URSI community lost a major technical and scientific contributor, colleague, and friend with the unexpected death earlier this year of Dr. A.D. (Don) Spaulding of the United States.



As noted by the Chairman of URSI Commission E, Prof. Viktor Scuka of Sweden, "All the members of URSI Commission E, and in particular the members of Commission E Working Groups, remember Dr. Spaulding as a a first-class scientist and a friend. It is a serious loss for the Commission's future scientific work. His loss is deeply felt!" Don had been retired from his long-time job at the U.S. Department of Commerce's Institute for Telecommunication Sciences (ITS) in Boulder, CO, for exactly six weeks when he suffered a fatal heart attack. While only Don's close friends knew he had been bravely battling multiple sclerosis (MS), none of us expected his sudden death in a field near Ft. Morgan, in Weld County, CO. Don had got out of his car to let out his golden retriever, Morgan, for an individual dog event during bird dog field trials on 15 April 1995. That was income tax day in the U.S. We have a saying that nothing is certain but death and taxes, but only a few people get both on the same day. But that tax day spared Don and his family a long period of suffering with MS, and for that we can be grateful.

It is a challenge to capture in a relatively short space the dimensions of our colleague, Don Spaulding. Statistical facts were always important to Don (e.g., see CCIR Report 660, which he and I coauthored, that defines spectrum occupancy as a random variable), and here are some that are pertinent to him. Don was born in Denver, CO, on 3 May 1935 to Art and Mildred Spaulding. He grew up in South Denver, was an honor student, and earned the highest rank (Eagle) in the Boy Scouts of America (BSA). Don enjoyed many fine scouting events with his dad, a prominent BSA leader in the Denver area. He was both active and competitive, and he accepted reasonable risks. During his high school years, Don enjoyed rock climbing, became a climbing guide, and climbed and guided in Mexico and the Canadian Bugaboos as well as in the U.S. Don was also an amateur taxidermist (specializing in duck decoys, which he named after the nephews of Walt Disney's Donald), and led a fencing team that won more than its share of matches against allegedly superior teams. He also enjoyed hunting, especially upland game like pheasants and migratory game like ducks and geese. These birds are best hunted with a good bird dog, and that also appealed to Don, who later took great pleasure in training his golden retrievers to excell at pheasants as well as ducks and geese: Brandy (1966), Mungo Park's Greeting (1975), and Top Brass Morgan Mackay, who was with Don preparing to show how well he had been trained when Don died.

Don was academically talented, and was awarded a full scholarship to the University of Colorado (C.U.) in Boulder. He earned both his B.S.E.E. (1957) and M.S. in Applied Mathematics (1960) at C.U., where he also earned a letter in gymnastics. In 1971, he completed his Ph.D. in Electrical Engineering at the University of Denver, under his world-famous mentor and thesis advisor (and long-time research collaborator), Dr. David Middleton. While in college, Don became a member of several academic honor societies including (Eta Kappa Nu, Tau Beta Pi, Signa Tau, and Sigma Xi). From 1958 to 1961 he also served as a instructor in the Department of Applied Mathematics at C.U. He learned from his students, his colleagues, and his family, and he continued to enjoy learning and teaching throughout his life. He even had the courage and bravery to tutor his daughter, Susan, in her college math courses. Don's brother Dick recalled at Don's funeral a joint climb up Mt. Rainier in the state of Washington when, in the middle of a fearsome glacier, Dick needed some reassurance. Don came back to him and said "Fear is just an experience. You are in a situation where you have no control over your destiny. Forget the fear and you will enjoy the beauty of it." That is the kind of philosophy and courage it takes to undertake to teach your own child something difficult (for the child) like math!

Don began a lifelong affiliation with the U.S. Department of Commerce (DOC) in 1957 when he joined the Tropospheric and Space Telecommunications Division of the Central Radio Propagation Laboratory. There he worked in the rich scientific and technical environment of Kenneth Norton (who found the error in Arnold Sommerfeld's formulation of the solution to Maxwell's equations for groundwave propagation and who later formalized the definitions of basic transmission loss, radio system loss, etc.), Jack Herbstreit, and Dick Kirby (both of whom later became Directors of the CCIR in Geneva), and Newbern Smith (who led the U.S. shortwave frequency prediction efforts during World War II before the move of the CRPL to Boulder. Don's own early technical work involved radiowave propagation and atmospheric noise. The noise part became a lifelong field of study for Don, and he quickly became an internationally recognized expert in this field. He initially worked under Bill Crichlow to help revise CCIR Report 65 on atmo- spheric noise predictions using data acquired during the International Geophysical Year (IGY) to create the famous CCIR Report 322, "Worldwide Distribution and Characteristics of

Atmospheric Radio Noise," published in 1964. He was part of a team that included his Boulder colleagues (C.J. Robique, R.T. Disney, Jr., W.M. Beery, and M.A. Jenkins). Don's friend Fred Horner from the Radio Research Station, Slough, United Kingdom, also spent 3 months in Boulder helping finalize the CCIR report and working on URSI Special Report 7. Don continued to revise CCIR Report 322 (to 322-1, 322-2, and finally the current 322-3—a truly major revision involving a remapping of the worldwide noise contours at 1 MHz based on data taken after the IGY).

In 1961, Don joined the Electromagnetic Interference Environment Program at what is now the Institute for Telecommunication Sciences (ITS) in Boulder. At ITS, Don has worked on measuring and modeling electromagnetic noise and electromagnetic interference (EMI), and he carried this basic work on through to the analysis and design of telecommunications systems operating in non-Gaussian noise environments. His thesis, published in two parts in the IEEE Trans. COM and co-authored with his advisor (Dr. Middleton) is a classic. Only recently has there been enough computer "horsepower" to make practical use in real-time systems of this pioneering work which grew out of the Middleton-Spaulding collaboration regarding the locally optimum detection of weak signals in the presence on non-Gaussian noise.

While at ITS, Don served for 9 years as the Chief of the Propagation Modeling and Applications Group of the Spectrum Division of ITS/National Telecommunica- tions and Information Administration (NTIA). While Don's employees benefited from his nurturing guidance, his main forte was his technical strength. He bypassed several opportunities for advancing in the ITS management, and he served ITS in a senior technical capacity until his retirement on 3 March 1995.

Don contributed to his profession outside of ITS by serving as an Associate Editor of what was then a U.S. URSI journal, RADIO SCIENCE, and (until more recently) the IEEE Trans. EMC. He was a member of the Technical Program Committees for both the Zurich (Switzerland) and Wroclaw (Poland) International EMC Symposiums, held in alternate years. Don was awarded prizes for the best paper on at least two occasions at these EMC symposia. His Gold Prize in 1977 was for a paper titled "Optimum Receiption in the Presence of Impulsive Noise." At the next symposium (Rotterdam, 1979), his paper was second only to the Gold Prize of his mentor, Dr. David Middleton. In Zurich, in 1985, Don's paper was again voted the best of the 115 papers given, and he won the Gold Prize. This paper was titled "Locally-Optimum and Suboptimum Detector Performance in Non-Gaussian `Broadband' and `Narrowband' Interference Environments.' These prizes (won on the basis of presentations in URSI-sponsored sessions) also carried a significant monetary award in Swiss francs, which Don (and David) richly deserved. Don's IEEE contributions were recognized by the Electro- magnetic Compatibility (EMC) Society in 1992 with a Certificate of Appreciation for his service as an Associate Editor for the IEEE Trans. EMC.

Within URSI, Don was Vice Chairman of U.S. URSI Commission VIII when it was formed, and he served as Vice-Chairman (1975-78) and Chairman (1978-81) of U.S. URSI Commission E. He also served several terms on the U.S. National Committee of URSI (USNC/URSI). He declined numerous nominations over the years for Vice Chairman of International URSI Commission E. He did serve as the Chair of several URSI Commission E Working Groups, both within the U.S. and internationally. Don also was active in the International Radio Consultative Committee (CCIR) of the International Telecommunication Union (ITU), Geneva, Switzerland. He served on many U.S. delegations, chaired Interim Working Parties (IWPs) and led the efforts on revisions to CCIR Reports 322 and 258, and he contributed technically to several CCIR Study Groups including S.G.s 1, 6, and 8. He also served on the URSI-CCIR-CCITT Liaison Committee (1984-1990). This liasion committee was formed due to the efforts of its first Chairman, Dr. John A. Saxton (UK), after the URSI Council voted to reemphasize telecommunications as part of a restructuring of URSI at the 1975 General Assembly in Lima, Peru. That URSI Assembly was Don's first, and he contributed to one of the first three Open Symposia in URSI history, Open Symposium C on "Electromagnetic Noise and Interference." I had organized this symposium after discussions with and at the suggestion of Prof. Henry Booker (USA) and M. Jean Voge (France), Vice Presidents of URSI who were considering the future of URSI at the 1972 General Assembly in Warsaw, Poland. I was con- cerned that young scientists like myself and Don could not go to the assemblies unless invited to give a paper. The scientific programs were closed, and (at least from the US) the delegations were limited in number and composed almost exclusively of the more senior members of the national URSI commissions. When I came home from that G.A. and told Don there was a chance to change that if the Lima Open Symposia were successful, he volunteered to help me. Open Symposium C was very successful; and, that success, at least in part,led to the URSI restructuring in Lima which included the formation of the current URSI Commission E. The terms of reference of Commission E have grown from the initial three (natural noise, man-made noise, and the effects of noise on system performance, the session titles of Open Symposium C), for which Don was a respected authority, to a much longer list. I want to recognize his help to me on organizing the open symposium in Lima that helped Commission E to be born, and to acknowledge his continuing help to that Commission through the years, as noted by its current Chairman, Prof. Scuka.

In 1985, Don's work on atmospheric noise was officially recognized by the U.S. Government when he was awarded the U.S. Department of Commerce Silver Medal for his work that led to the only major revision to CCIR Report 322 (322-3). The citation for the prize, shared with his ITS colleague James S. Washburn, read "For outstanding technical contributions in the furtherance of atmospheric radio noise estimation in telecommunications systems," 13 November 1885.

The "Donald", as his wife sometimes called him, had earlier been recognized (somewhat less formally) for authoring the classic ITS report, "Man-Made Noise: The Problem and Recommended Steps Toward Solution," published in 1976. Don was noted for his sense of humor, and this may have been the first official ITS report to contain a cartoon. I was honored to have worked on it with Don and to have contributed several appendices to that report, done by Don for our mutual friend, Donald M. Jansky (nephew of Karl Jansky, the pioneer of radio astronomy) of the Office of Telecommunications Policy (OTP), Executive Office of the President. He and his colleague, Robert T. Disney, had analyzed data taken by ITS for the U.S. Air Force on man-made noise, and they did regression fits to the data showing that the slope of the effective antenna noise figure, Fa (in dBkTo) was about -27.7 dB/decade, "on the average," regardless of where the data acquisition system was located. What changed was the reference point (in a point-slope approach to modeling the data). This led to a classic paper they co-authored for an IEEE meeting in Philadelphia, but you may recognize the result better as CCIR Report 258 on man-made noise which gave predictions for business, residential, rural and quiet rural areas. David Sailors (of the Navy's research facility in San Diego), another close professional colleague of Don's, and I were able to add only a little to what Don and Bob had accomplished in generating the original report which, by now, is up to its fifth revision regarding the text. But the equations are still the ones Don helped develop. This work is used, along with Don's atmospheric noise model, in almost all shortwave (HF) computer prediction codes in the world.

At the request of his friend George Lane (of the Voice of America), Don looked into the equation for combining noise from various sources into the overall system noise figure for a receiving system. He found and corrected several potentially serious errors. But the "corrected" equations kept occasionally producing erroneous results. Several people pointed this out to Don, and Don's friend George Hubbard determined the exact conditions where Don's formula did not apply. The expedient solution was to revert to the old (but known to be incorrect) solution in codes such as IONCAP, ICEPAC, and VOACAP. Don's friend, Lowell (Speedy) Minor looked into this and discovered the approximation for which Don had taken too few terms. He greatly enjoyed discussing this with Don in Boulder while at the 1995 U.S. National Radio Science Meeting held in January. Don, although ill from a respiratory problem, came in to talk about this with Speedy. Rather than being disappointed because someone had found a problem with his prior work and come up with a solution, Don was very happy indeed. That is part of the many positive dimensions of this recently lost colleague.

Don's long-time personal friend, Tom Wise, noted at his funeral that Don viewed life as a contact sport, and it was his characteristic that he "seized the moment." According to his brother, Dick, Don believed in God: "He said it was logical." Tom Wise phrased it differently: "Throughout his ongoing education, his exploring of the wonders of nature, from her mountain tops to her placid lakes, to the very laws of physics of atmospheric radio wave propagation [and natural noise], Don was convinced of God's presence. And so Don's faith grew stronger the more he lived and the more he learned." I learned from him about this also, but regrettably we only discussed it once. We were together on a boat from Geneva to Montreux in 1977 enroute to the EMC Symposium. Don had suggested the boat rather than the more conventional rental car or train. I now know that he did this because he "seized the moment," and I was a fortunate beneficiary. As we looked across Lake Geneva and all of it's beauty, Don noted that it was not that way by chance.

Don was a devoted husband and father, and he "practiced what he preached." After an IEEE EMC symposium in San Antonio, Don spent about 7 hours going from place to place trying to get the very freshest cilantro to take home to to Jennifer for her Mexican cooking. He only had to spend 2 minutes looking for the type of hot sauce he enjoyed (made from habanero peppers, the hottest). Every Friday, he stopped on his way home from work to get flowers for his wife. Don's love of exploration led him many places. He explored mathematics (most recently in cyberspace with his friend Arthur George Hubbard, doing chaos- related parlor games on computers powerful enough to solve Middleton's equations), the mountains, and various other exotic places. Many of the latter permitted him to combine his vocation with his avocations. For example, when he was involved in URSI, the General Assemblies almost always involved interesting and mysterious place like the Great Pyramid in Egypt, where he rode a camel after the 1987 URSI General Assembly in Tel Aviv; or the canals of Venice, where the photo of Don (above) was taken by Jennifer Spaulding (his wife since 17 February 1962), on the weekend break at the 1984 URSI General Assembly in Florence; or even in Washington, DC (which is at least mysterious to some of us) during the 1981 General Assembly. At Don's first URSI General Assembly (Lima, 1975), he took the opportunity to visit the ancient Inca city of Machu Pichu high in the Andes near Cuzco, Peru. Again, URSI gave Don a chance to "seize the moment." This time he took advantage of it by getting some South American clothing for Jennifer, who was unable to make that particular trip, and a full-size poster of Machu Pichu.

All of his adult life, Don continued to enjoy the outdoors, and his interests included hiking, camping, skiing (water and snow), jogging, and running in races (5K, 10K, etc. as Don was always into things for the long pull). Don is survived by his wife of 33 years, Jennifer, of Lakewood, CO; his son Kent and his bride Tracy, of Austin, TX; his daughter Susan, of Denver, CO. Other close relatives include his brother Dick of Colorado Springs, CO, his wife Carolyn, and their children (Christopher, Timothy, and Marnie); and his cousin Lyman Spaulding, his wife Susan (after whom Don and Jennifer named their own daughter), and their children Lisa, Adam, and Anclaire.

Don also is survived by his numerous URSI and CCIR (now ITU Radiocommunica- tion Sector) friends and colleagues (many of whom happen to be the same individuals), who are honoring him by reading here about his life. Others, including his ITS/DOC friends and colleagues will honor Don by attending a special U.S. URSI Commission E session being held in conjunction with the 1996 U.S. National Radio Science Meeting in Boulder, CO, on 11 January 1996 (7:00 to 10:00 PM) at Don's alma mater, C.U. Speakers include: G.H. Hagn (Chair), E.K. Smith, D.B. Sailors, L.C. Minor, D. Middleton, R.D. Parlow, C.M. Rush and R.J. Matheson. A special abstract booklet will be available to attendees. If you are unable to attend this Boulder session, please pause at that time and remember Don and his many contributions to radio science. Fortunately for us, Don was a prolific author who believed in sharing what he had learned, and we can use the truly archival material he has left for many generations to come. But we will still miss him, especially about the time the next URSI or IEEE meeting rolls around.

Respectfully submitted,

George H. Hagn
Past Chair, URSI Commission E (1978-1981)
Past Chair, URSI-CCIR-CCITT Liaison Committee (1984-90)

75th ANNIVERSARY

URSI - 75 Years
Space and Radio Science
Symposium

MOBILE COMMUNICATION SYSTEMS AND BIOLOGICAL EFFECTS ON THEIR USERS

Maria A. Stuchly

Introduction

Influences of electricity and electromagnetic fields on biological systems were observed as early as the 18th century (Galvani) and the 19th century (d'Arsonval). A rigorous inquiry started after the Second World War. The interest in this field has been to a large extent stimulated by the worker and public concerns and pressures regarding safety of proliferating technologies. The main effort has concentrated in two frequency ranges: power line frequencies (50-60 Hz), and radio frequencies (RF) including microwaves. Considerable progress has been made in understanding the interactions of RF fields with living systems [1-3]. This understanding and agreement among the majority of scientists and regulators have resulted in very similar or nearly the same recommendations regarding safe exposure levels in many national standards and international guidelines [4].

Engineering contributions in dosimetry have made it possible to compare the results of biological investigations performed on various animals and to extrapolate them to the human exposure. Dosimetry is defined as theoretical and experimental evaluation of induced electric fields in tissue [5,6]. The descriptive parameter that is widely used is the specific absorption rate (SAR), i.e., the rate of energy deposition in a unit mass of tissue. The highlight of the RF dosimetry has been establishing how the average SAR depends on the field frequency and the size of the exposed body. The use of the SAR for dosimetric purposes does not in itself presume or is limited to thermal effects. The only implication it carries is that the fields induced in the body are responsible for biological interactions rather than the external exposure field itself. With the help of dosimetric modeling, thresholds of the SAR were established for various effect in animals [1-3]. Most effects appear to be associated with thermal load due to RF exposure and are characterized by thresholds. The main limitation of the data base is a lack of well-performed chronic studies, and the paucity of data for ELF (extremely low frequency) amplitude modulated fields.

More recently, concerns have been expressed about cellular telephones and other personal communications services (PCS). There are two main issues. The first relates to the deposition of energy (SAR) in the head. In some cases up to 50% of the device output power may be deposited in the user's head. The second issue relates to new technologies which improve the efficiency and channel utilization through digital modulations. This results in the amplitude (pulse) modulation at extremely low frequencies (ELF) of microwave signals. Because the same or similar bio-effects have been observed at RF amplitude modulated at ELF as at exposures to ELF alone, there is an uncertainty regarding health risks. The issues briefly mentioned above are discussed in more detail in this paper.

1. Physical Interactions

Interactions of radio frequency (RF) and microwave fields with biological tissues and bodies are complex functions of numerous parameters. Dosimetry quantifies these interactions. In free space the fields are characterized by the frequency strength of the electric and magnetic fields, their direction and polarization. The fields induced inside the body depend on the electrical properties of various tissues. The magnetic permeability ($\hat{\mu}$) of biological materials is equal to that of vacuum and therefore, can be neglected in considerations of the induced fields. The dielectric permittivity [$\hat{\varepsilon} = e_o(e' - je'')$ where e_o is the permittivity of

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vacuum] of biological tissue depends on the type of water content tissue (e.g., fat, muscle), temperature and frequency. The real part of the relative permittivity (e') is called dielectric constant. The imaginary part of the relative permittivity (e') is related to the conductivity (e'') in the following way:

$$\sigma = 2\pi f \varepsilon_0 \varepsilon'' \qquad (1)$$

where: f is the frequency. The values of both the dielectric constant (ε') and loss factor (ε'') or conductivity (σ) vary substantially in the frequency and tissue type [7].

The dielectric permittivity and frequency also determine how far the electromagnetic wave penetrates into the body. The penetration depth varies from a small fraction of a millimeter at the upper frequencies of microwave range (above 100 GHz), to a few centimeters for high water content tissue at frequencies of a few GHz and for low water content tissue at frequencies of a few tens of GHz to over 1 m for low water content tissue at 10 MHz.

The quantification of the internal fields in complicated biological medium such as a human or animal body is, in general a difficult task due to the irregular shapes and heterogeneity of the material properties. However, only the fields inside the tissues and biological bodies can interact with them, and therefore it is necessary to determine these fields for any meaningful and general quantification of biological data obtained experimentally.

Fields inside biological bodies exposed to known external electromagnetic fields can be calculated by solving Maxwell's equations subject to given boundary conditions and taking into account the tissue electrical properties. The inhomogeneity of the dielectric properties and the complexity of the shape make a solution, or sometimes even a full formulation of the problem, a difficult task. Only simplified models can be analyzed. The other approach is an experimental one, which is also subject to considerable limitations.

The intensity of the internal fields depends on the parameters of the external field, the frequency, strength and polarization, on the size, shape and the dielectric properties of the exposed body, on the spatial configuration between the exposure source and the exposed body, and on the presence of other objects in the vicinity. With a complex dependence on so many parameters, it is apparent that the internal fields in a mouse and a man exposed to the same external field can be dramatically different, and so will be their biological response, even not taking into account physiological differences. Conversely, different exposure conditions, i.e., at different frequencies, may induce similar fields inside such diverse shapes as a mouse and a man.

A dosimetric measure that has been widely adopted is the specific absorption rate (SAR) defined as "the time derivative of the incremental energy (dW) absorbed by, or dissipated in an incremental mass (dm) contained in a volume element (dV) of a given density (r)" [1].

$$\mathrm{SAR} = \frac{d}{dt}\left(\frac{dW}{dm}\right) = \frac{d}{dt}\left[\frac{sW}{\rho(dV)}\right] \qquad (2)$$

Using the Poynting vector theorem for sinusoidally varying electromagnetic fields, eq. (2) can be expressed as:

$$\mathrm{SAR} = \frac{\sigma}{2\rho}|E_i|^2 = \frac{\omega\varepsilon_o\varepsilon''}{2\rho}|E_i|^2 \qquad (3)$$

where σ is the tissue conductivity in S/m, ε_o is the dielectric constant of free space

$$\left(\varepsilon_o = 8.85 \times 10^{-12}\ \mathrm{F/m}\right),\ \varepsilon''$$

is the loss factor, $\omega = 2\pi f$, f is the frequency in the Hz, Ei is the peak value of the internal electric fields in V/m. The average SAR is defined as a ratio of the total power absorbed in the exposed body to its mass. The local SAR refers to the value within a defined unit volume or unit mass, which can be arbitrarily small.

The SAR can be considered both as thermal and non-thermal dosimetric measure. For athermal biological effects that depend on the electric field strength, the SAR can be considered as an appropriate measure. The rate of temperature increase is also directly proportional to SAR, and equal to:

$$\frac{dT}{dt} = \frac{\mathrm{SAR}}{C} \qquad (4)$$

where T is the temperature, t is the time and C is the specific heat capacity.

Considerable progress has been made in theoretical and experimental dosimetry. General review of theoretical and experimental methods and results are available [8,9]. The whole-body-average SAR for exposures in the far-field for a given body, is a function of frequency and polarization. Figure 1 illustrates a typical dependence, in

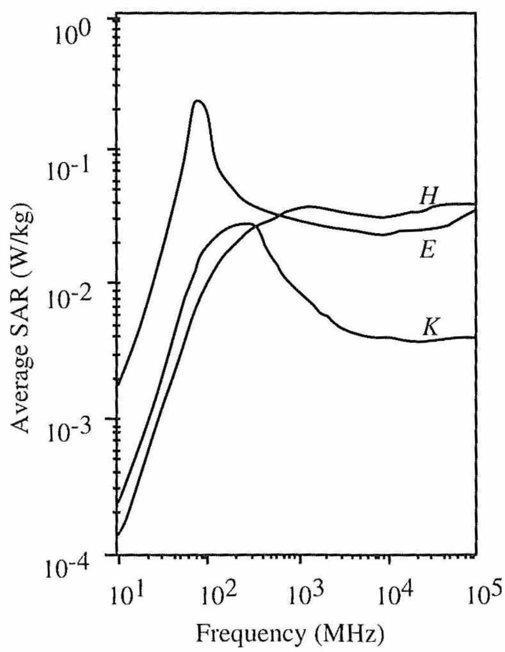

Fig. 1 - The average SAR in an average man (175 cm, 70 kg) exposed to a uniform plane wave of 1 m/Wcm^2. E polarization designates the electric field parallel to the long axis of the human body, H polarization designates the magnetic field parallel to the long axis, and K the propagation vector parallel to the long axis.

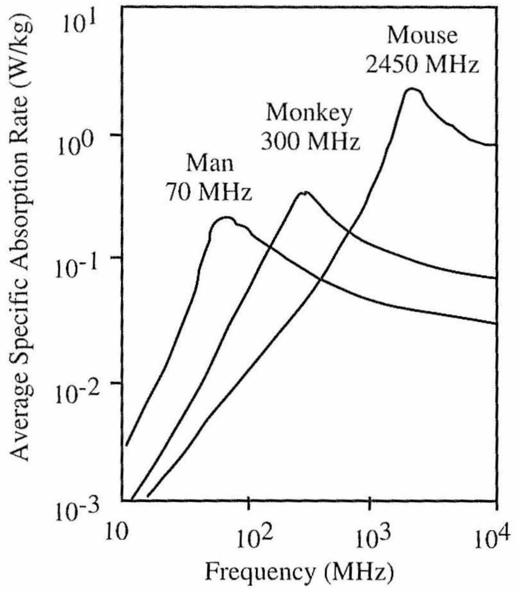

Fig. 2 - The average SAR in three species of mammals exposed to a uniform plane wave of the E polarization and a power density of 1 mW/cm². Approximate resonant frequencies are indicated.

this case for a model of an average man (175 cm, 70 kg) exposed in the far-field to 1 mW/cm². The E-polarization corresponds to the electric field parallel to the main body axis, H-polarization to the magnetic field parallel to the main axis of the body, and the k-polarization to the wave propagation from head-to-toe. The maximum absorption occurs at about 70 - 80 MHz for the E-polarization. This frequency is referred to as the resonant frequency for man. It should be noted that at this frequency, the power absorbed is a few times greater than that obtained by multiplying the surface area of the body cross-section by the incident power density. For a man standing in contact with RF ground, the resonant frequency shifts to about 30-40 MHz, and the SAR increases by about a factor of two. The average SAR depends also on the size and shape of the body, as illustrated in Fig. 2, which shows the SAR curves for three species for the E-polarization at 1 mW/cm² [8,9].

The spatial distribution of the SAR is highly non-uniform. For man at frequencies above 5 GHz the energy is deposited close to the body surface. It is at frequencies between 30 to 300 MHz, that high local SARs occur in the head and torso. At frequencies below 50 MHz for a man in contact with RF ground, very high local SARs are produced in the ankles [3]. The non-uniformities are particularly pronounced in the near-field [11,12]. Figures 3 and 4 show local SARs in the neck and the lung of a man exposed in the far-field in the E-polarization [11]. In the near-field, even greater non-uniformities in the SAR are produced[10,12].

2. Biological Effects

The dosimetric data on average SARs, i.e., as shown in Figures 1 and 2, are useful in extrapolating observed

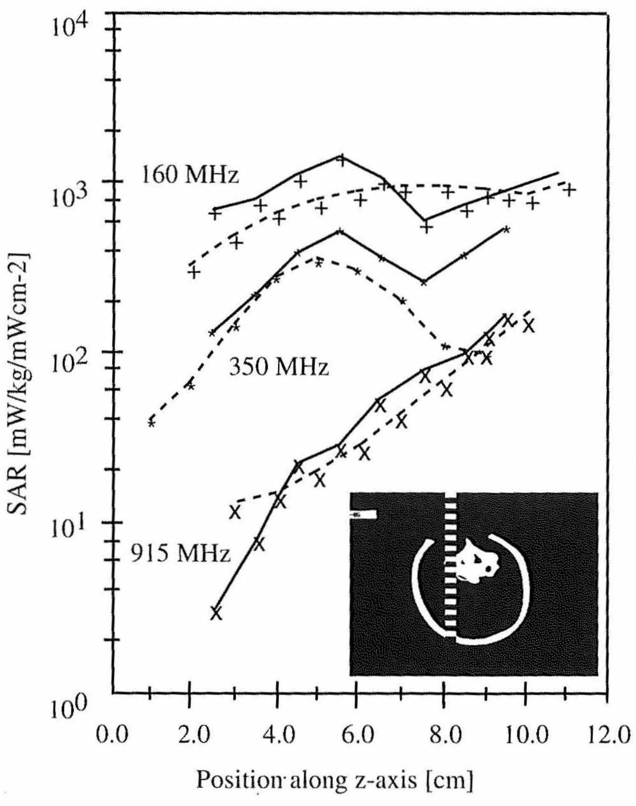

Fig. 3 - Experimentally determined local SARs along the path in the neck as marked on the insert. Exposure to 1 mW/cm², E polarized uniform plane wave.
***Solid lines** - heterogeneous model of man.*
***Dashed lines** - homogeneous model of man.*

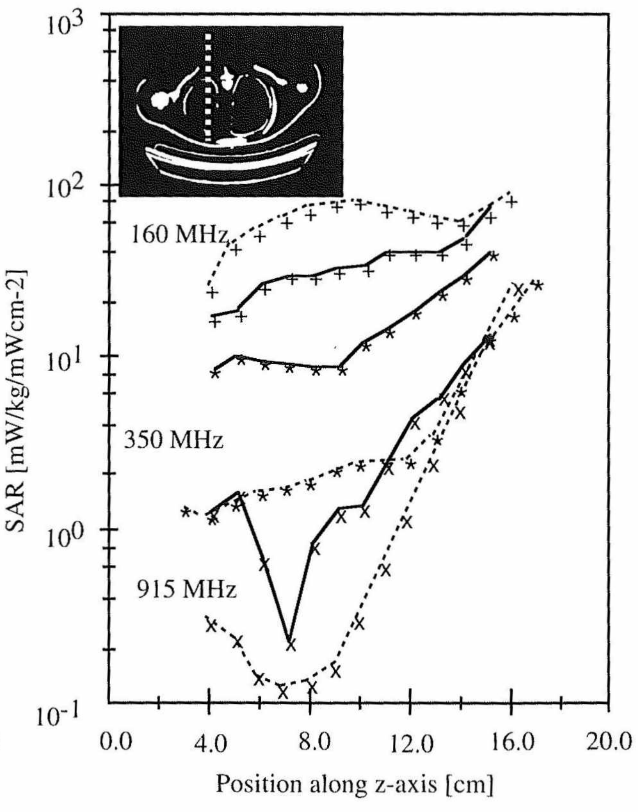

Fig. 4 - Experimentally determined local SARs along the path in the lung as marked in the insert. Exposure to 1 mW/cm², E polarized uniform plan wave.
***Solid lines** - heterogeneous model of man.*
***Dashed lines** - homogeneous model of man.*

effects in animals to those expected in man. For example, if a mouse and a man are exposed at 1 GHz, the average SAR in the mouse is about ten times greater than that in man. Hence, if a biological effect is observed in a mouse at a given power density, a greater power density would be expected to be necessary to cause the same effect in man. Such extrapolation, however, does not take into account differences in spatial distribution of the SAR illustrated in Figures 3 and 4.

Biological effects of radio and microwave fields have been extensively investigated as documented in several reviews [1-3,13,14,15]. With the help of dosimetric modeling, thresholds of the average specific absorption rate (SAR) or rates of energy deposition in tissue in watts per kilogram have been established for various effect in animals. Some examples follow, however a comprehensive review with a full statistical analysis is not attempted here. Data quoted is from the published reviews. Radio frequency radiation is teratogenic in rodents at SARs that approach lethal levels, and a threshold for induction of birth defects is associated with the maternal core temperature of 41-42°C [1,13,15]. Chronic exposure of rats during gestation at 2.5 W/kg was reported to result in lowered fetal body weight at weaning [1]. Temporary sterility in male rats occurred at a SAR of 5.6 W/kg, which produced a core temperature of 41°C [1]. Decreases in operant and learned-behavioral responses occur when SAR = 2.5 W/kg in the rat and at 5.0 W/kg in the rhesus monkey. Some types of behavior are affected when SARs are approximately 25-50% of the resting metabolic rate. These behavioral changes are reversible with time, after exposure ceases. Changes in the endocrine system and blood chemistry occur when SARs are greater than 1 W/kg and changes in hematologic and immunologic systems occur when SARs are equal or greater than 0.5 W/kg for prolonged exposures and appear to be associated with thermal stress[1,15]. One group of researchers reported that chronic exposure of SARs at 2-3 W/kg resulted in cancer promotion or co-carcinogenesis in mice [16]. The effect was similar to that caused by chronic stress. Neurons in the central nervous system were altered by chronic exposure at 2 W/kg [1]. All these effects appear to be associated with thermal load due to RF exposure and are characterized by thresholds [1-3, 13-15].

In summary, for whole-body exposures to RF/MW radiation, the experimental data currently available strongly suggests that biological effects in mammals occur when the average SARs are between 1 to 4 W/kg. This database is well established and consistent. This fact has been reflected in more recent exposure standards [4]. Each of these documents contain a reference either in the text or in the accompanying publication to the same database [1-3, 13-15]. The main limitation of the data base is a lack of well-performed chronic studies, and the paucity of data for ELF amplitude modulated fields. It needs to be emphasized that in the case of cellular telephones and other PCS devices, exposure is localized, and whole-body average SARs are not directly applicable.

3. Current Issues and Concerns

Wireless mobile communica-tions presents new challenges in terms of health effects. There are two main issues. The first is microwave power from a cellular telephone. The second issue relates to new technologies which improve the efficiency and channel utilization through digital modulations (e.g., time division multiple access - TDMA, or code division multiple access - CDMA), and use of frequency shift-keying (FSK) or phase shift keying (PSK). This results in the amplitude (pulse) modulation at extremely low frequencies (ELF) of the microwave signal. Some of the same or similar bio-effects have been observed at RF, however, there is an uncertainty regarding health risks of amplitude modulated at ELF as at exposures to ELF.

4. Local Energy Deposition

An evaluation of spatial distribution of SAR from cellular telephones and other mobile RF transmitters presents challenging problems both theoretical and experimental. The main difficulties are due to geometrical complexities and electrical heterogeneity of biological tissue. Several theoretical and experimental investigations of the SAR distribution in various models of the human body have been conducted [10,17-25]. Not until the 1990's have numerical techniques been developed that provide satisfactory treatment of the problem. Earlier experimental investigations have established several important features of the energy absorption in the head of a user of a portable transmitter. The early investigations using a full-scale model of human body with heterogeneous electrical properties representing various tissues and resonant antennas indicated that:

(i) there are significant (an order of magnitude) differences in SARs in various locations between heterogeneous and homogeneous models having the same shape,
(ii) the maximum SAR is produced at the surface of the model (across from the feedpoint), and the SAR close to the surface of the model decreases exponentially with distance in the direction perpendicular to the surface, and
(iii) most of the energy is deposited in about 20% of the total body volume closest to the antenna feed point [10].

Another experimental evaluation was also performed. Notably two portable transceivers were assessed, one operating in the range of 810-820 MHz and the other operating at 850-860 MHz [20]. A heterogeneous model of the head was used with simulated skull, brain, eye, and muscle tissues. Similarly, as in [10], a maximum of the electric field on the surface and decay with distance were observed. The estimated maximum SARs on the surface of the eye were 3.2 and 1.1 W/kg per 1 W of the input power for the 810-820 MHz transmitter and 850-860 MHz transmitter, respectively. These values decreased to 1.1 and 0.7 W/kg per 1 W when the transmitter was moved 2.5 cm away from the head.

With the recent advances in the finite-difference time-domain (FDTD) technique and in computers (memory and speed), a viable tool has become available for analysis of SAR in the head due to various cellular telephones. Several groups are actively pursuing research in this area.

There have been numerous reports at recent conferences. Results of some of these investigations have already been published or are in press [17-19, 21-25]. There are a few more reports accepted and submitted for publication that cannot be quoted at this time. A general picture that emerges indicates that between 10 - 50 % of the transmitter output power is absorbed in the model of a human head. The low absorption has been typically reported for antenna separations from the head of the order of 4 cm. About 50 % of even more of the antenna output power is absorbed in the head for separations of the order of 1 cm. Peak SARs reported range from 2 to 8 W/kg per 1 W of output power. Lower SARs are produced within bigger volumes of the tissue, but average SARs of over 3 W/kg in the eye have been predicted by some researchers.

There appears to be considerable confusion and disagreements with respect to the interpretation of the reported results of numerical calculations and measurements. Frequently, the data that are actually in a nearly perfect agreement is interpreted in vastly diverse ways. There are at least some apparent reasons for this phenomenon. One problem, likely a serious one, results from not sufficient attention paid to the effect of various telephone configurations. Antenna shape and feedbox, distance from and location, with respect to the head model, are a few of the most important parameters that affect the SAR in the head. Other physical differences relate to various models of heads used, and the unspecified (or not evaluated) accuracy of the results reported. The other type of problems relate to the differences in interpretation of the actual results. While not necessarily erroneous, averaging over larger tissue volumes and time averaging, and interpretation of the results with respect to the current exposure standards, tend to obscure the data and deter from their objective comparisons. Applying in unqualified manner conditions of the current exposure standards to the data for cellular telephones is only of a limited value. The current standards have been developed on the basis of body average SARs and therefore are not formulated, neither the best suited to deal with exposures resulting in a very low average of SARs. There is a definite need to establish agreed upon methods of numerical and experimental evaluation of cellular telephones. This would permit meaningful comparisons of various designs of telephones, as well as data obtained in various laboratories. Activities of this type have recently commenced among several European centers.

Another interesting development relates to a new design of antennas for cellular telephones, particularly diversity antennas. An example of such effort has recently been reported [17]. Power absorbed in the head and other parts of the human body is lost from the communications perspective. A human body also significantly alters the radiation pattern. Therefore, modeling of the effect of the user's body on performance of cellular telephones and the minimization of the power deposited in the body illustrate good engineering sense. At the same time, the SAR in the head is decreased with such designs, even though at present the medical evidence is lacking that would indicate any real harm. Only a limited amount of work on investigations of various antenna configurations from this point of view have been published [17,19]. However, research in this area appears to have been carried out at a few laboratories.

5. Biological Effects of Modulated RF Fields

Biological effects have been observed at RF and MW fields amplitude modulated at ELF at SAR levels below thresholds for effects for continuous waves [1,14,26]. Many of these effects are the same or similar to effects observed for ELF electric and magnetic fields. The observed effects are usually field frequency and intensity specific. They tend to occur within relatively narrow ranges of both field parameters, and are dependent on other physical and physiological characteristics of the exposed biological system. Many of these parameters have not been fully identified and characterized. The interaction mechanisms remain unknown. The scientific database is relatively limited in this area. However, the potential importance of these effects should be critically evaluated. The scientific evidence with respect to health effects of ELF fields, while inconclusive, is suggestive of possible detrimental effects. Until the recent developments in digital communication there were hardly any situations of human exposure to RF/MW fields deeply amplitude modulated at ELF. This situation is changing rather rapidly with expansion of wireless digital communication.

The last decade witnessed considerable scientific effort as well as public concern regarding potentially harmful effects of human exposure to ELF and more specifically the power line frequency fields. The main concern is due to a number of epidemiological studies that have shown associations between exposure to low magnetic flux densities (of the order of 0.2 - 0.3 μT) and rates of childhood leukemia [e.g. 27-29]. Similarly suggestive evidence between the rates of some cancers and occupational exposures have been provided by epidemiological studies of various cohorts of workers [e.g. 30,31]. Several recent reviews outline the results and evaluate the limitations of the studies [32-34]. The limitations of some studies range from surrogate measures of exposure to very small numbers of cases in high exposure groups limiting the statistical power of the findings. While most of these studies suffer from at least some limitations, the weight of the evidence cannot be dismissed. The main problem is a limited amount of experimental data that could support the findings of the epidemiology. There are some experimental results that may at least partly support the proposition that ELF fields affect the development of cancer, but the overall picture remains ambiguous.

A few studies of carcinogenicity have been done on animals. Large scale studies are now underway. Cancer development is considered in experimental models as a multistage process involving initiation (a change in the cell genetic material - DNA), promotion and progression. Promotion is associated with repeated exposures to an agent which may also act as an initiator (e.g. X-rays) or only as a promoter (many chemicals). Promotion involves interactions at the cell membranes. Progression is the last stage involving rapid growth of tumor and metastasis. Since electromagnetic fields have not been found to cause genetic changes, most investigations have been concentrating on promotion and co-promotion. As co-promotion, one considers modification either through an accelerated rate of development or a greater incidence of cancer produced by two chemical agents, both an initiator and a promoter. Three studies, two in Sweden [35-36] and one in Canada [37], have shown that magnetic fields do not act as promoters. Another Canadian study has shown that a relatively strong magnetic field accelerated the rate of chemically developed tumors in mice, but not the final yield in terms of the number of tumors and the number of animals affected [38]. One Swedish study [35] did not show any co-promoting effect, and the other showed a slight inhibition of the rate of tumor growth [36]. Recent Swedish studies show that intermittent exposures may be effective in cancer promotion by relatively strong magnetic fields [39]. While there appears to be some biological interaction, at least in some cases, the actual effect magnetic fields have, if any, in cancer development remains undetermined. There has been a plethora of laboratory investigations of various isolated cells in culture. These studies have clearly shown that electromagnetic fields of low frequencies can interact with biological systems at moderately low intensities. Typical responses reported were an altered cell growth rate, decreased rate of cellular respiration, altered metabolism of carbohydrates, proteins and nucleic acids, changes in gene expression and genetic regulation of cell function, and altered hormonal responses. Recently, further observations were reported regarding effects on cellular transcription, charge on the cell surface, ATP and oxygen levels in the slime mold, growth, proliferation, and functional differentiation of cells. Several studies have reported changes in calcium efflux. Another important effect of ELF fields is suppression of melatonin production and alterations in circadian rhythms. Effects on melatonin have been shown both in-vitro and in animals [26,33]. Many of these in-vitro effects are related to cancer development, but are also associated with other regulatory processes.

The main problem in evaluations of biological effects of ELF fields is the complexity of observed interactions. Effects observed are not always proportional to the field strength or the magnitude of induced currents. Sometimes, they show "window" responses in the field frequency and amplitude, and cell physiological state. The critical parameters responsible for the effect are often not well defined nor are they understood.

6. Conclusions

Interactions of radio and microwave energy with biological systems have been investigated vigorously for nearly half a century. A lot has been learned and thresholds for harmful effects have been established. Development of RF dosimetry, a quantification tool, has provided means for extrapolation from animal experiments into assessment of risks to human health. By the late eighties, health protection standards in various countries had converged to nearly identical limits. This reflects their reliance on the same data base and the agreement in its interpretation.

Current proliferation of devices and new services in mobile communications have raised new concerns. These concerns mostly relate to the relatively large rates of energy deposition in some parts of the body, mostly the eye and the brain, and to the data transmission resulting in the amplitude modulation of RF signals at ELF. The energy deposition is being currently evaluated for various devices using modern computational techniques. This problem is likely to be resolved in the near future, resulting perhaps in specific guidelines for device use. It is interesting to note in this context, that antenna designs that are optimal from the communications point of view also deposit the smallest amounts of energy in the device user.

The question of ELF modulation is more difficult to answer. Independent of what is the final assessment of health impact of ELF fields, it does not directly translate to the same or even similar assessment for microwave fields modulated at ELF. There is no reason to suspect any specific harmful effects related to ELF amplitude modulation of radio or microwave fields if ELF studies indicate that the detrimental impact on human health is minimal or none. On the other hand, if ELF exposures result in risks to people, that would not translate into the same risks for exposures to microwaves modulated at ELF, but would provide motivation and rationale for research into the potential problem.

Acknowledgment

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MEASUREMENT OF MESOSCALE OCEANIC AND ATMOSPHERIC PHENOMENA BY ERS-1 SAR

WERNER ALPERS

Abstract

Radar images acquired over the ocean by the synthetic aperture radar (SAR) aboard the First European Remote Sensing Satellite ERS-1 delineate oceanic as well as atmospheric phenomena. The oceanic phenomena visible on ERS-1 SAR images include surface waves, internal waves, eddies, oceanic fronts, underwater bottom topography, and surface slicks. The atmospheric phenomena include katabatic wind fields, convective cells, atmospheric boundary layer rolls, internal gravity waves in the atmosphere, atmospheric vortex rows (Karman vortex streets) behind islands, and atmospheric nonlinear wave disturbances. Examples of ERS-1 SAR images showing sea surface manifestations of mesoscale oceanic and atmospheric phenomena are presented and interpreted in terms of oceanic and atmospheric models.

1. Introduction

On July 17, 1991, the First European Remote Sensing Satellite ERS-1 was launched by the European Space Agency (ESA). It carries a C-band (5.3 GHz) synthetic aperture radar (SAR) operating at vertical polarization for transmission and reception. In the full SAR mode (geometric resolution: 25 m, swath width: 100 km) SAR data can be collected for a period of 10 minutes per orbit (period: about 100 minutes). As of November 28, 1995, a total number of 890511 ERS-1 SAR scenes have been acquired : 319936 scenes by ESA receiving stations and 570575 by foreign (non-ESA) receiving stations like the ones located at Tromsø (Norway), Fairbanks (Alaska), O'Higgins (Antarctica) West Freugh (Scotland), Alice Springs (Australia), and Bangkok (Thailand). Up to this date ESA has distributed via its Processing and Archiving Facilities (PAFs) 34400 ERS-1 SAR products to users.

Analyses of ERS-1 SAR data have demonstrated that ERS-1 SAR imagery of the ocean surface contains a wealth of information that can be used in oceanographic and marine meteorological studies.

Preliminary results obtained from the analysis of ERS-1 SAR data can be found in the Proceedings of the First and Second ERS-1 Symposia held in Cannes, France, 4-6 Nov., 1992 (ESA publication SP-359) and in Hamburg, Germany, 11-14 Oct., 1993 (ESA publication SP-361), respectively, and in the Proceedings of the "ERS-1 Geophysical Validation Workshop" held in Penhors, Bretagne, France, 27-30 April, 1992 (ESA publication WPP-36).

2. Mesoscale oceanic phenomena

Mesoscale oceanic phenomena like internal waves, oceanic eddies and fronts, become visible on SAR images because they are associated with variable surface currents which modulate the surface roughness (Fu and Holt, 1982; Alpers, 1985; Johannessen et al., 1992). Figures 1 and 8 show ERS-1 SAR images of the Strait of Gibraltar on which roughness patterns associated with nonlinear internal waves propagating eastwards can be delineated. Other ERS-1 SAR images of the Strait of Gibraltar showing sea surface manifestations of internal wave forms can be found in Alpers and La Violette (1992), Brandt and Alpers (1994). If slicks are floating on the sea surface, mesoscale oceanic phenomena become also visible by the spatial distribution of the slick material on the sea surface (Gower, 1993). Surface slicks are often encountered in coastal regions with

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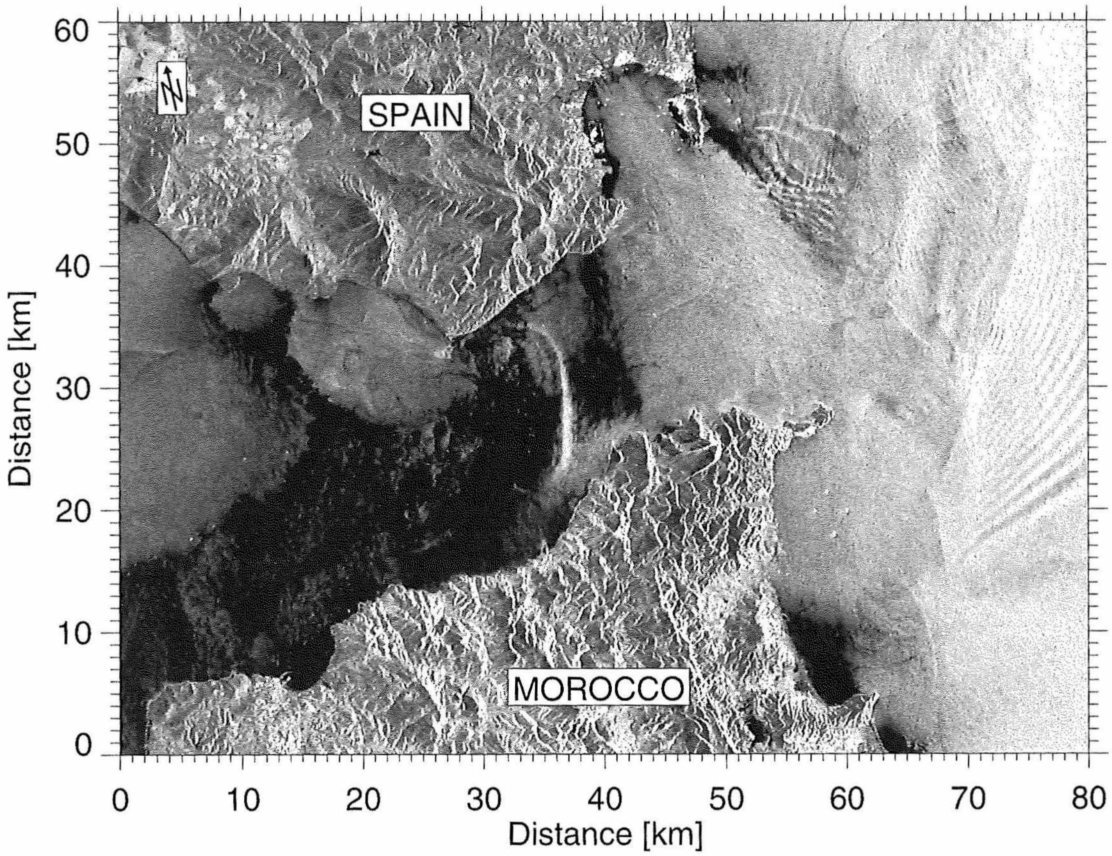

Fig. 1 - Section of an ERS-1 SAR image of the Strait of Gibraltar acquired on Jan. 20, 1994, at 11:03 UTC (orbit 13151, frames 2871/2889). It shows sea surface expressions associated with an internal soliton in the Strait (bended bright line) and an internal wave packet east of the Strait which was generated during the previous tidal cycle.

Fig. 2 - ERS-1 SAR image (100 km x 100 km) of the Baltic Sea acquired on Apr. 16, 1994, at 21:04 UTC (orbit 14390, frames 1089/1107). It shows in the center sea surface patterns caused by natural surface films. In the lower left hand corner the German island of Ruegen and on the upper edge the coast of Sweden are visible.

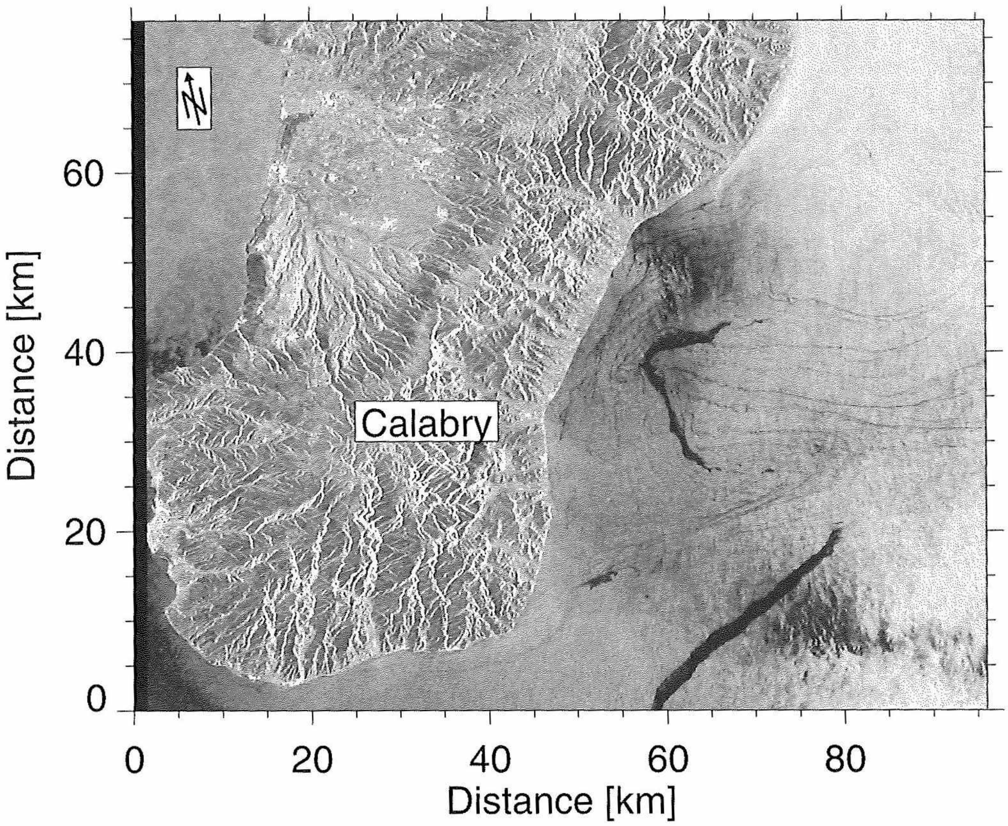

Fig. 3 - ERS-1 SAR image (100 km x 75 km) of the Mediterranean Sea (Ionian Sea) and the southern part of the Italian peninsula (Calabry) acquired on Aug. 31, 1994, at 9:38 UT (orbit 11117, frame 2835). It shows two large dark streaks off the east coast of Calabry which very likely are due to oil spills released by a ship

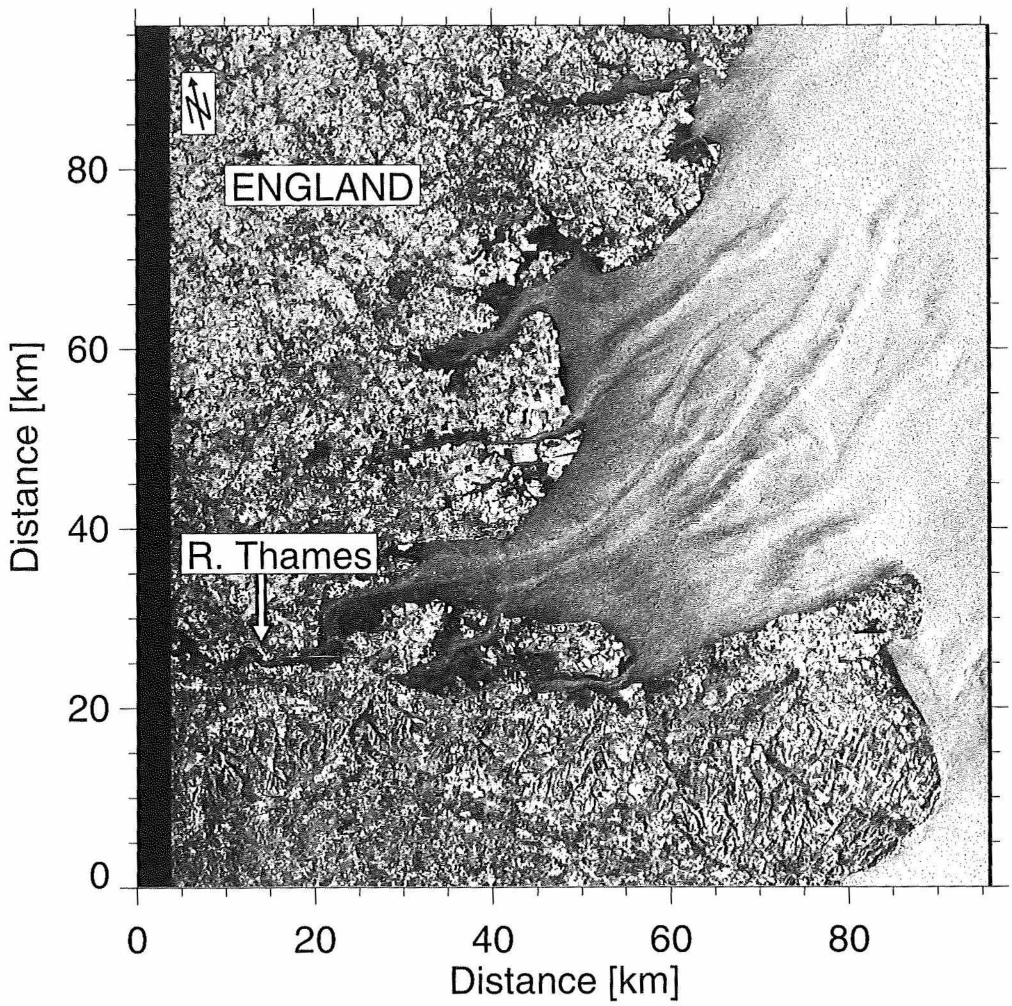

Fig. 4 - ERS-1 SAR image (100 km x 100 km) of the estuary of the river Thames (England) acquired on Jan. 21, 1993, at 10:52 UT (orbit 7940, frame 2565). It shows sea surface manifestations of sandbanks located in the estuary at a time of strong tidal flow.

high biological productivity, especially in the summer, where they follow the underlying water movements. An example of an ERS-1 SAR image delineating slick patterns is shown in Figure 2.

Mineral oil spills can also be detected on ERS-1 SAR images as shown in Figure 3. They damp the short surface waves and thus reduce the radar backscatter (Hühnerfuss et al., 1986).

Underwater sandbanks located in areas of strong tidal flow are also visible on ERS-1 SAR images. An example is shown in Figure 4. The underwater sandbanks modulate the tidal flow which in turn modulates the sea surface roughness and thus the radar backscatter (Alpers and Hennings, 1984).

3. ERS-1 SAR images of atmospheric phenomena

An imaging radar is capable of delineating mesoscale and submesoscale atmospheric phenomena because they are associated with variations of the wind stress at the sea surface. The wind stress depends on the wind speed at the sea surface and on the stability of the air-sea interface which is a function on the temperature difference between the water and the air (Keller et al., 1989). Changes in the wind stress at the sea surface disturb the small-scale sea surface roughness and thus give an "imprint" on the sea surface which is visible on radar images. The synthetic aperture radar (SAR) aboard the First European Remote Sensing Satellite ERS-1 is much more sensitive to changes in the wind stress than the SAR aboard the Seasat satellite because

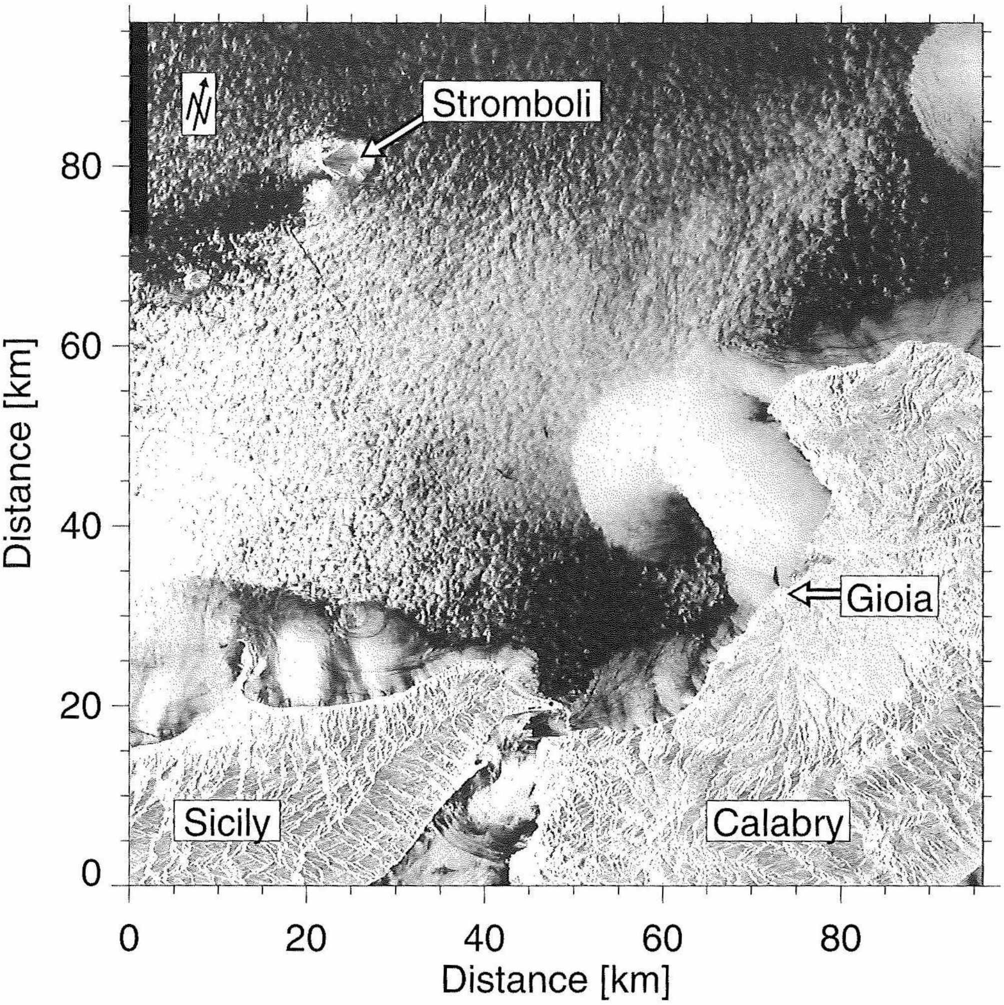

Fig. 5 - ERS-1 SAR image (100 km x 100 km) of the Mediterranean Sea (Tyrrhenian Sea) north of the Strait of Messina (Italy) acquired on Sept. 8, 1992, at 21:13 UT (orbit 6014, frame 765). It shows north-west of Gioia sea surface manifestations of a katabatic wind tongue (bright blob in the image). Furthermore, between the island of Stromboli and the Sicilian coast, a granular pattern can be delineated which we believe are sea surface "imprints" of atmospheric convective cells. This cellular structure is destroyed in the vicinity of the Sicilian coast by the katabatic wind blowing from the mountains onto the sea. In the lower section of the image an oceanic internal wave train propagating southwards in the Strait of Messina can be delineated.

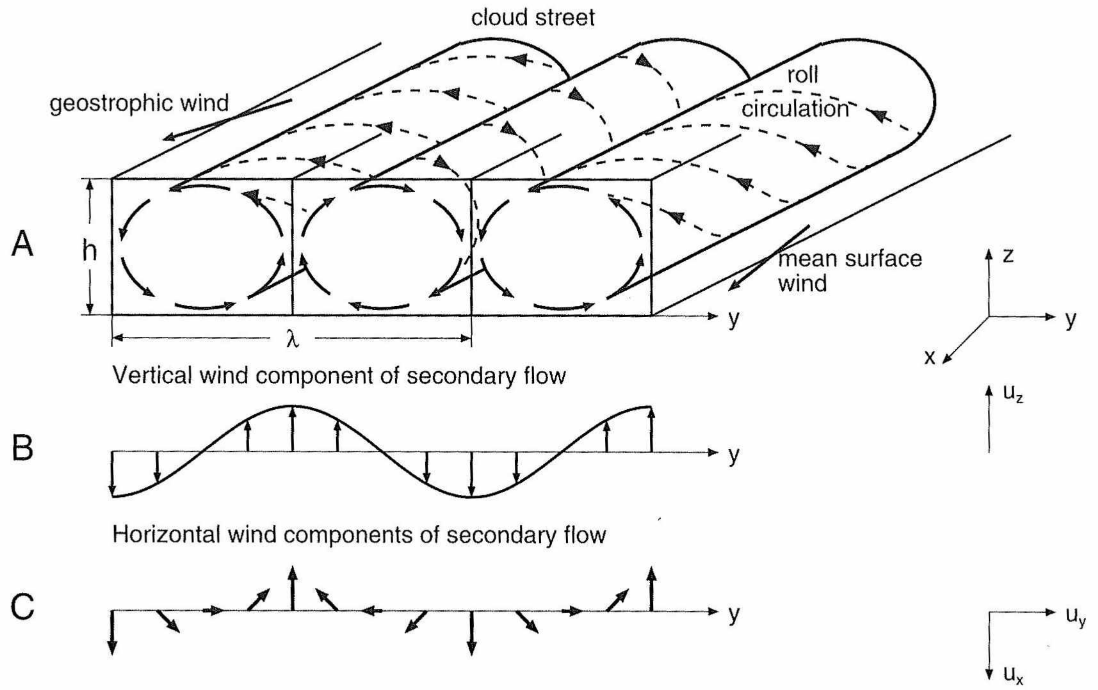

Fig. 6 - Schematic plot of secondary flow pattern associated with atmospheric boundary layer rolls. Panel A: Perspective view of the three-dimensional flow; Panel B: Variation of the vertical component u_z of the wind velocity along the y direction; Panel C: Variation of the horizontal components u_x and u_y (in the x-y plane).

the ERS-1 SAR operates at C-band (wavelength: 5.7 cm) and not at L-band (wavelength: 24 cm) like the Seasat SAR. For ERS-1 SAR (incidence angle: 23°, VV polarization), the slope of the wind scatterometer model function is 1.1 while for Seasat SAR (incidence angle: 23°, HH polarization) it is only 0.5 (Alpers and Brümmer, 1994). Thus the ERS-1 SAR should be more suitable for studying atmospheric phenomena than the Seasat SAR. This can be seen by comparing ERS-1 and Seasat SAR images acquired over the ocean.

3.1 Katabatic wind fields

Katabatic winds are cold winds blowing in the evening and night down a sloping terrain ("gravity flow") and, at a coast, over the adjacent sea surface. These winds are generated because in the evening and night the air near the surface cools off faster over the land than over the sea. Over mountain slopes a horizontal density difference develops between the cooled air at the slope surface and the free air in the same altitude over the lower ground or the sea. This results in a "down-hill" flow of cold air. Sea surface manifestations of katabatic wind fields have often been identified in the summer on ERS-1 SAR images of coastal regions which are adjacent to mountainous areas. Figure 5 shows an example of a katabatic wind field which extends from the Calabrian coast near the Italian town of Gioia into the Tyrrhenian Sea. Also patterns arising from katabatic winds which are channeled through valleys in northern Sicily can be delineated north of the Sicilian coast.

It is also possible to extract the distribution of sea surface wind velocities from ERS-1 SAR images by using an ERS-1 wind scatterometer model function (The wind direction has to be inferred from the orientation of the valley and from the form of the katabatic tongue).

3.2 Convective cells

Convective atmospheric cells are generated over the sea when the water temperature is higher than the air temperature (unstable marine boundary layer) and when the wind speed is low. The cellular features visible in Figure 5 between the island of Stromboli and the Sicilian coast are very likely sea surface manifestations of such convective atmospheric cells. Such features can often be delineated on ERS-1 SAR images taken over the Mediterranean Sea on calm days during summer. These quasi-regular features are absent in a coastal sector adjacent to the northern Sicilian coast (see Figure 5). We suspect that there the organized cellular circulation pattern in the unstable marine boundary layer is destroyed by coastal processes associated with the katabatic wind field blowing from the northern Sicilian mountains through the valleys.

3.3 Atmospheric boundary layer rolls

Atmospheric boundary layer rolls are helical circulation patterns in the atmospheric boundary layer which are superimposed on the mean wind field, i.e., the primary flow (see Figure 6). They can be generated either by thermal instability (Rayleigh-Bénard instability) when the layer is

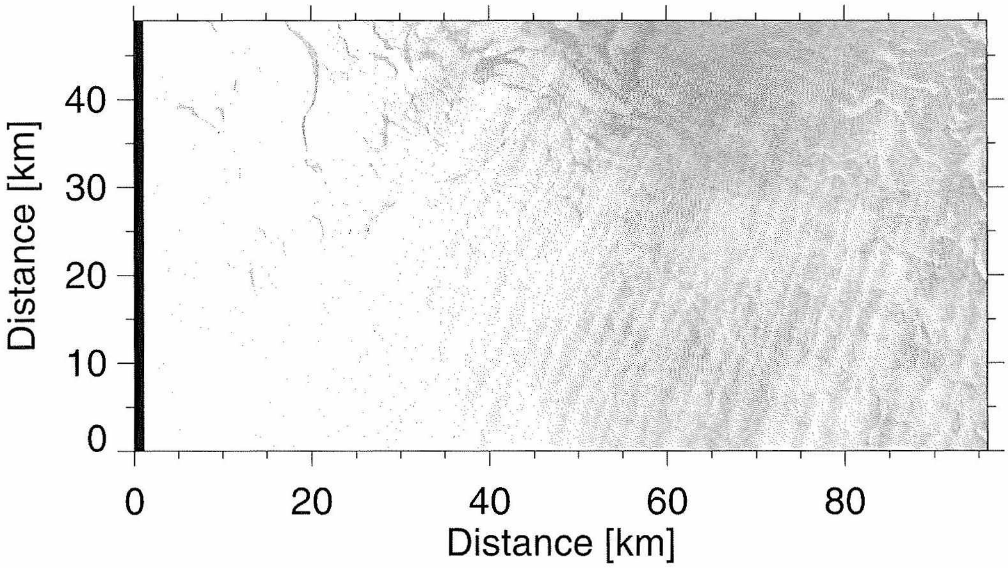

Fig. 7 - ERS-1 SAR image (100 km x 50 km) of the marginal ice zone west of Spitsbergen in the Greenland Sea acquired on March 5, 1993, at 19:41 UT (orbit 8561, frame 1629). It shows sea surface manifestations of atmospheric boundary layer rolls generated by a strong cold wind blowing off the ice over the warm sea (cold air outbreak). The ice edge is located in the upper part of the image.

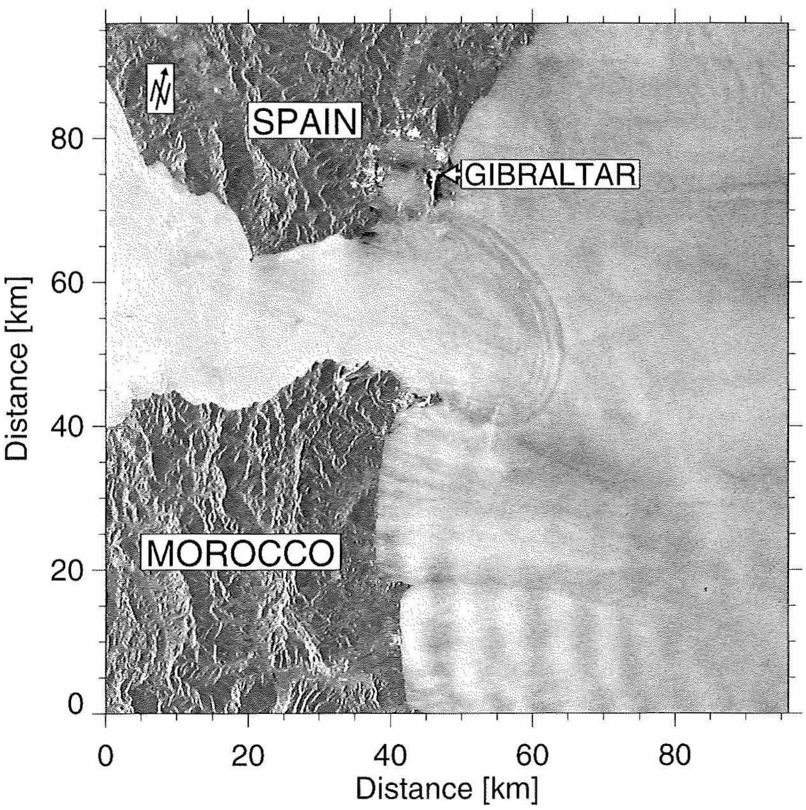

Fig. 8 - ERS-1 SAR image (100 km x 100 km) of the Strait of Gibraltar acquired on Sept. 3, 1993, at 22:39 UT (orbit 11168, frame 711). It shows in the center sea surface manifestations of an oceanic internal wave packet generated in the Strait of Gibraltar and in the lower right hand section sea surface manifestations of atmospheric internal waves (lee waves) generated by an eastward blowing wind over the 600 m high mountain range Sierra del Hauz in Morocco.

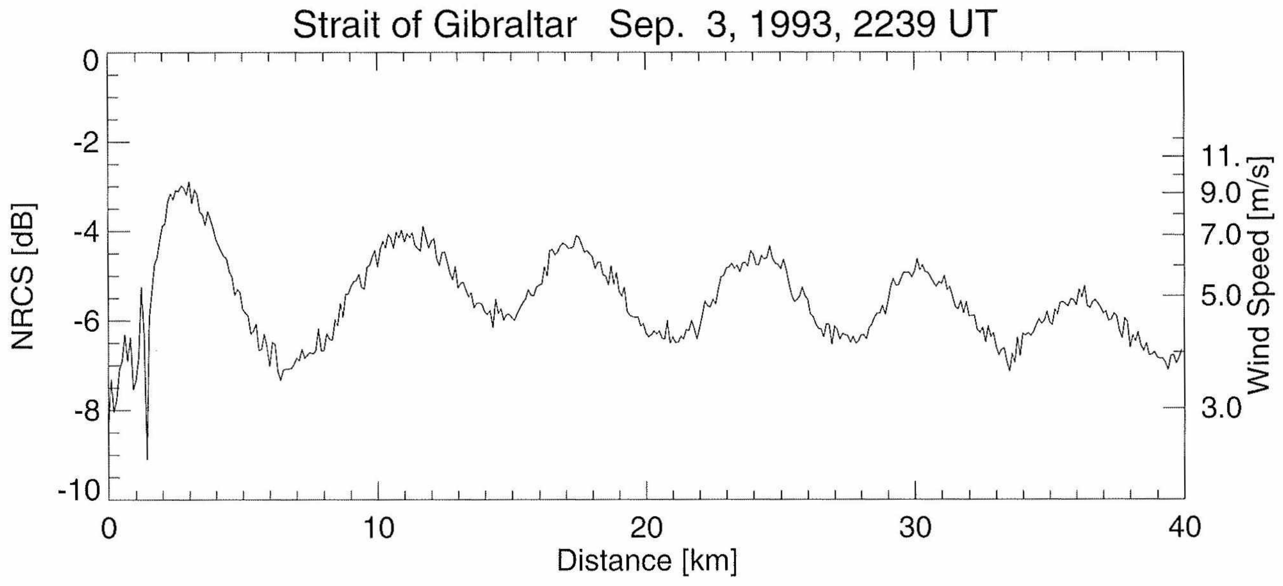

Fig. 9 - Image intensity scan from west to east through the internal lee wave pattern east of the Moroccan coast shown in Fig. 8. On the left-hand vertical coordinate axis the normalized radar cross section (NRCS) is plotted and on the right-hand vertical coordinate axis the wind speed at a height of 10 m above sea level (under neutral wind conditions).

heated from below or cooled from above, or by dynamic instabilty (inflection point instability) when the wind velocity changes with height in such a way that an inflection point occurs in the wind component normal to the roll axis. The axes of the boundary layer rolls are oriented between the directions of the mean surface wind and the geostrophic wind above the boundary layer. Usually the boundary layer is capped by an inversion so that the depth of the boundary layer and the roll layer coincide. In the case of a thermal instability, the aspect ratio, i.e., the horizontal wavelength of the roll pattern, l, divided by the roll height, h, is 2.8 according to the linear Rayleigh-Bénard convection. However, the most frequently observed values range between 2 and 4.

If the moisture conditions are favorable, cloud streets may be formed in the upward rising branches of the roll circulation. Atmospheric boundary layer rolls contribute significantly to the vertical exchange of momentum, heat, and moisture in the atmosphere. At higher altitudes their relative contribution to the total vertical fluxes in the atmosphere can even be larger than the turbulent fluxes.

Sea surface manifestations of atmospheric boundary layer rolls have first been noted on L band SAR images which were acquired over the Atlantic ocean off the coast of Florida during the Marineland Experiment in 1975 from a NASA airplane (Thompson et al. 1983). Later such features have also been observed in L band SAR images from the Seasat satellite (Fu and Holt 1982), and from Space Shuttle Columbia during the Shuttle Imaging Radar-A (SIR-A) experiment (Ford et al. 1983), and in X band real aperture radar (RAR) images from various Russian satellites (Mitnik 1992). However, all these radars were not well calibrated, and therefore it was not possibe to extract quantitative information on sea surface wind variations from the radar images. This is, however, possible with the ERS-1 SAR since it is a calibrated instrument.

Figure 7 shows sea surface manifestations of atmospheric boundary layer rolls acquired over the Greenland Sea when a cold wind was blowing off the ice over the warmer sea surface. The streaks are aligned approximately in wind direction. The horizontal separation of the streaks increases with increasing distance from the ice edge. This increase is linked to an increase of the height of the atmospheric boundary layer with distance from the ice edge.

Other examples of sea surface manifestations of atmospheric boundary layer rolls visible on ERS-1 SAR images can be found in the paper by Alpers and Brümmer (1994).

3.4 Internal waves in the atmosphere

Atmospheric internal gravity waves exist in layered atmospheres. They either occur as quasi-periodic waves or as solitons. They are often generated behind mountain ranges in which case they are called lee waves. In the steady state lee waves are stationary with respect to the terrain feature, but they are propagating relative to the mean air flow above the earth surface. Lee waves are very common in visible remote sensing imagery where they manifest themselves as wave-like cloud patterns.

However, they also can manifest themselves on the sea surface since they are associated with a varying surface stress which modulates the small-scale sea surface roughness. An example of an atmospheric lee wave visible on an ERS-1 SAR image in the Mediterranean Sea is shown in Figure 8. The atmospheric lee wave is generated by the interaction of an eastwards blowing wind (approx. 7 ms^{-1}) with the Sierra del Hauz mountain range in Morocco.

Figure 9 shows an image intensity (grey level) scan normal to the eastern Morrocan coast line through the lee wave pattern. The image intensity has been converted into normalized radar cross section (NRCS) by using the conversion (calibration) factor provided by ESA. Furthermore, the normalized radar cross section can be related to the wind speed by using a C band wind scatterometer model. The wind speed scale calculated from the CMOD 4 model (Stoffelen et al. 1992) is plotted on the right-hand vertical coordinate axis.

3.5 Atmospheric nonlinear wave disturbances

Figure 10 shows an ERS-1 SAR image of the German Bight of the North Sea which was acquired on March 18, 1992, at 10:25 UT. The wave-like pattern visible east of the island of Heligoland is not a sea surface manifestation of an oceanic internal wave, but of an atmospheric nonlinear wave disturbance propagating eastwards. The identification of this feature as an atmospheric wave disturbance has been possible because simultaneous in-situ meteorological measurements were carried out at the island of Heligoland. At Heligoland the German Weather Service had erected a 80 m high meteorological mast at which wind and temperature measurements were performed every minute at height levels of 10 m, 30 m, 50 m, and 80 m. A wind with a height-averaged mean wind speed of 3.0 ms^{-1} was blowing at the time of this ERS-1 overflight from 170° N. Twenty-nine minutes before the ERS-1 SAR image was taken, a pronounced periodic wind fluctuation in east-west direction was observed at Heligoland. The period of the wind fluctuations in the reference frame moving with the wind was 9.5 minutes and the wavelength 2300 m. The wind speed fluctuations at 10 m height ranged from -1.2 ms^{-1} to 1.7 ms^{-1} (Alpers and Stilke, 1996).

This nonlinear wave disturbance is either a solitary wave disturbance or an undular bore propagating on a stably-stratified layer in the lower atmosphere. The most spectacular examples of nonlinear atmospheric wave disturbances are the undular bores, which often occur near the southern coast of the Gulf of Carpentaria in Northern Australia (Smith 1988) and which are called "Morning Glories". The name "Morning Glory" derives from an

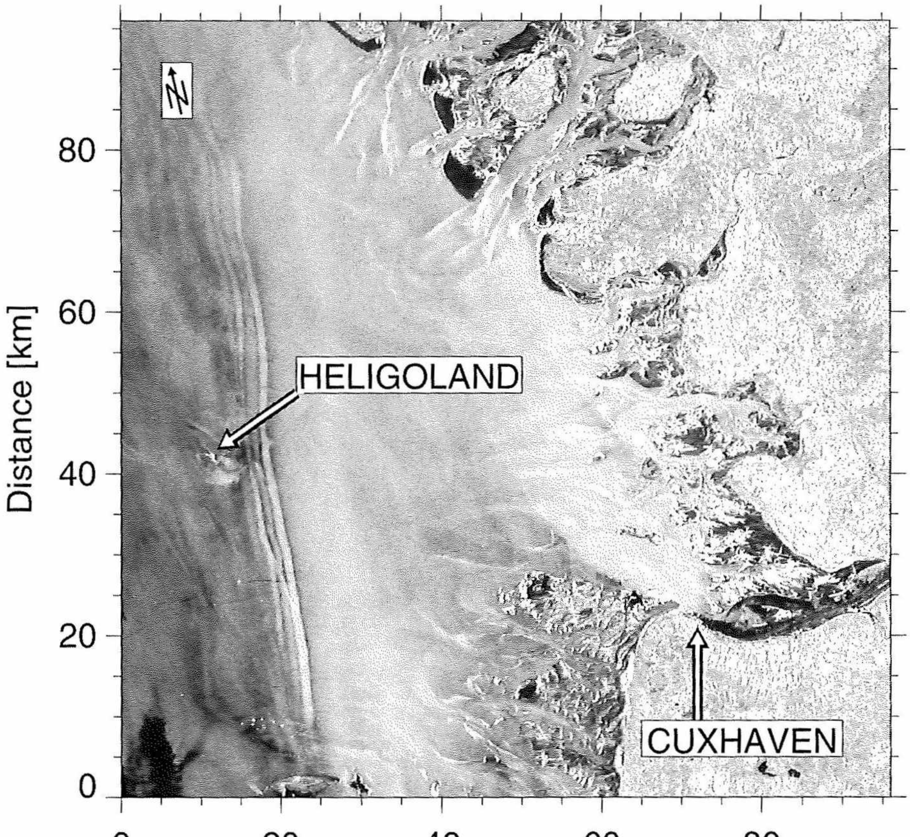

Fig. 10 - ERS-1 SAR image (100 km x 100 km) of the German Bight of the North Sea acquired on March 8, 1992, at 10:25 UT (orbit 3373, frame 2511). It shows a wave-like pattern east of the island of Heligoland which is an imprint on the sea surface of the atmospheric nonlinear wave disturbance generated by an atmospheric cold front propagating eastwards. The bright streaks near the coast are sea surface manifestations of underwater bottom topographic features.

impressive roll cloud, or series of roll clouds, which occurs early in the morning, most frequently at the end of the dry season. They are associated with surface wind gusts and with pressure jumps on the order of few hectopascals.

However, atmospheric solitary waves have also been observed in other parts of the world (Doviak and Ge 1984). One example are the "Berlin Fog Waves of October 11, 1969", reported by Scherhag (1969) and Egger (1985). There exist several reports by pilots of small aircraft and crew members of small sailing boats who encountered a suddenly occurring succession of strong wind squalls or wind gusts of varying direction, the period of which is typically 5-10 minutes. These unexpectedly occurring strong wind squalls associated with atmospheric solitary waves can become dangerous to small landing aircraft (Christie und Muirhead 1983).

The generation of atmospheric nonlinear wave disturbances is usually linked with the intrusion of colder, denser air into a stably or indifferently layered atmosphere. On March 8, 1992, a cold front was moving from west to east over the German Bight. Like atmospheric lee waves, atmospheric solitary waves and undular bores are associated with a varying wind stress at the sea surface and thus with a varying small-scale sea surface roughness which is detectable by radar. By applying a wind scatterometer model, variations in image intensity can be converted into variations of wind speed.

Acknowledgments

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Interference of Little LEO Satellites on Radioastronomy Services. A case study

P. Delogne
C. Van Himbeeck

1. Introduction

Radioastronomy (RAS) is one of these fundamental sciences which should be protected in a civilized society. Radioastronomers observe the sky with extremely sensitive instruments. Their measurements can be seriously perturbed and sometimes made impossible when transmitting satellites cross the main beam or even the side lobes of a RAS antenna.

Some frequency bands have been allocated by ITU-R to RAS. Harmful interference most frequently result from out of band radiation by satellites operating in neighbouring frequency bands. Particular concern is frequently expressed about the spectral side lobes of spread spectrum signals (SS). In the absence of spectrum limitation, a SS signal has a power spectral density of the type $\left[\sin(\pi f / f_c) / (\pi f / f_c)\right]^2$ which decreases very slowly outside the main lobe, which bandwidth is roughly equal to $1.5 f_c$. Here, f_c is the chip frequency, a chip being a symbol of the spreading square wave. It once happened that RAS services have been considerably perturbed during several years by a satellite transmitting SS signals without any filtering of out of band radiation. This incident, which is obviously unacceptable, is probably at the origin of the general fear of radioastronomers about SS systems. The objective of this paper is to show, through a case study, that out of band radiation can be perfectly controlled in well-designed SS systems.

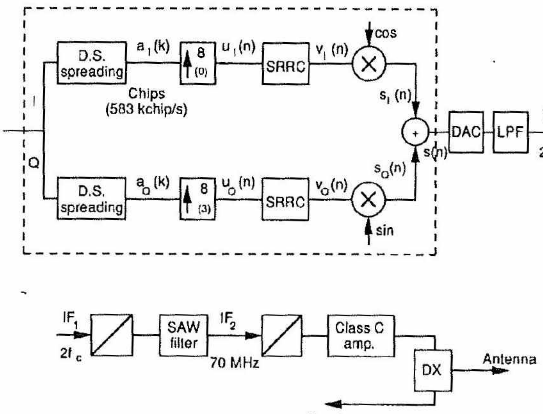

Figure 1 : Block diagram of the IRIS transmitter

The case under study is that of a so-called Little LEO (Low Earth Orbit) satellite with name IRIS. This satellite, presently under project, will fly at an altitude of 400 km and will transmit a spread spectrum signal with a power of 2 watt at a center frequency of 400.6 MHz. The chip frequency f_c is about 538 kHz, which means that the nominal bandwidth of the SS signal is about 700 kHz. Link budget calculations show that the maximum surface power flux density of this signal at the ground level is equal to -183 $dBW / m^2 Hz$.

We are here concerned with harmful interferences from this signal in VHF-UHF frequency bands allocated to RAS. According to ITU Recommendation 769, these frequency bands and the corresponding harmful values of the surface power flux densities are :
150.05-153 MHz, -255 $dBW / m^2 Hz$,
322-328.6 MHz, -258 $dBW / m^2 Hz$,
406.1-410 MHz, -259 $dBW / m^2 Hz$.
The problem investigated here is that of signal shaping, i.e. essentially filtering. We will not investigate other important questions such as spurious radiation due e.g. to local oscillator or mixer harmonics. Our objective is hereby limited to checking that the relative side lobe level is lower than (-259+183)=-76 dB below the main lobe at frequencies spaced by more than 5.5 MHz from the carrier.

2. Block diagram of the IRIS satellite transmitter

Figure 1 illustrates the block diagram of the IRIS transmitter. The modulation used is OQPSK (Offset Quadrature Phase Shift Keying) with spectrum spreading. The input data are therefore split into the I (In phase) and Q (Quadrature) channels and are then spread by pseudo-random sequences. The spread spectrum sequences $a_I(k)$ and $a_Q(k)$ have a chip rate of f_c = 583 kchip/s. For the present analysis they will be considered as random sequences of symbols taking the values ±1.

OQPSK belongs to the class of linear modulations. Digital communications theory tells how to design such systems to operate in a strictly limited bandwidth with

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optimum performances [1]. In the theoretical model used, all filtering actions are reduced to baseband. The input signal of the theoretical model is a train of Dirac impulses amplitude modulated by the symbols. At the other end, the received signal is sampled. These samples are used as the input to a decision device which estimates the transmitted symbols. The global channel transfer function $H_g(f)$ is defined as the transfer function between the Dirac impulses input and input to the receiver sampler. It is the product of the transmit and receive filters transfer functions. There are two basic problems to be solved in the design of the channel, namely intersymbol interference (ISI) and additive noise. Nyquist has shown that it is possible to transmit symbols at a rate f_cf without any ISI in a strictly band-limited channel provided this bandwidth is larger than $f_c / 2$ and the transition curve from pass to stop band in $H_g(f)$ is symmetrical w.r.t. the point with coordinates $(f = f_c / 2, H_g = 1/2)$. Such a filter with a symmetrical slope is currently called a Nyquist filter.

A frequently used Nyquist shape is the raised cosine filter

$$H_c(f) = \begin{cases} 1 & for(1) \\ 0.5\left\{1 - \sin\left[\pi\left(f/f_c - 0.5\right)\right]\right\} & for(2) \end{cases}$$

$$(1)\ 0 \le |f| \le (1-a)f_c / 2$$

$$(2)\ (1\text{-a})f_c \le |f| \le (1+a)f_c / 2 \qquad (1)$$

where the parameter $a < 1$ is called the roll-off factor. This transfer function strictly limits the baseband to $|f| < (1+a)f_c / 2$ and thus the RF bandwidth to $(1+a)f_c$.

The other requirement to be met is optimum performance in the presence of additive noise. It is known that this is obtained when the transmit and receive filters form a matched pair, i.e. their transfer functions are complex conjugates of each other. The ISI and noise requirements are therefore simultaneously fulfilled when these transfer functions are equal to the square root of a Nyquist transfer function. Such a filter is sometimes called a half-Nyquist filter. Thus the transmit pulse shape is the impulse response of a half-Nyquist filter.

In the IRIS satellite, pulse shaping is performed in the digital modemshown inside the broken line rectangle on figure 1. The digital modem operates with eight samples/chip, i.e. at a sampling frequency $f_s = 8f_c$. The symbol sequences $a_I(k)$ and $a_Q(k)$ are therefore decimated by a factor 8, i.e. 7 null samples are inserted between symbols. The only difference between the I and Q branches is in the phase (0 and 3) of the interpolators : $u_Q(n)$ must indeed be delayed by half a chip period w.r.t. $u_I(n)$ as required by offset QPSK. These sequences are the Dirac pulse trains applied to the input of square root raised cosine (SRRC) filters performing the transmit pulse shaping ; in the IRIS design, a roll-off factor $a = 0.4$ .is used Thus, the sequences $v_I(n)$ and $v_Q(n)$ are the Rice components of the OQPSK signal, i.e. the complex amplitude of this signal is $v_I(n) - jv_Q(n)$.

It was a design choice to include in the digital modem a transfer at a first intermediate frequency with carrier frequence $(2f_c)$. Therefore the sequences $v_I(n)$ and $v_Q(n)$ are multiplied by samples of a cosine and of a sine at this frequency. As these samples takes only the values $(-1, 0, 1)$, this modulation operation is quite easy. Thus, the sum $s(n) = s_I(n) + s_Q(n)$ is a sequence of samples of a OQPSK signal with carrier frequency $(2f_c)$.taken at the rate $8f_c$ The analog signal at this first IF is obtained after digital to analog conversion followed by lowpass filtering.

As shown on figure 1, the signal is then transferred to a second intermediate frequency at 70 MHz, where out of band signals are damped by a surface acoustic wave (SAW) filter, and then converted to the output frequency of 400.6 MHz. A duplexer is used to connect the transmitter and the receiver to a common antenna. It may be interesting to mention that the receive band 385-390 MHz is separated from the transmit frequency by only 10 MHz. Therefore the path between the transmitter and the antenna necessarily contains a quite selective transmit filter which will obviously also reduce out of band radiation in the RAS band 406.1-410 MHz.

3. The digital modem

In this section we will analyse the spectra of signals inside the digital modem for the actual IRIS design. These signals are sequences. For those readers who are not familiar with digital signal processing techniques, let us recall that the spectrum of a sequence is the same as that of a train of Dirac impulses modulated in amplitude by this sequence. Is is periodic in frequency with a period equal to the sampling frequency. It is common practice to express sequence spectra in function of the normalised frequency $F = f / f_c$ with $|F| \le 0.5$ considered as the basic period. For real signals, spectra exhibit complex conjugate symmetry $G(-F) = G^*(F)$. Therefore spectra are shown in the interval $0 \le F \le 0.5$, which thus corresponds here to actual frequencies in the range $0 \le f \le 4f_c$.

A theoretical SRRC filter has a strictly limited bandwidth and, consequently, its impulse response $g_t(n)$ has infinite duration and cannot be implemented in practice. The actual impulse response $g(n)$ of the filter is obtained by applying a temporal window to $g_t(n)$. In the IRIS design, a rectangular window of 8 chips has been used. With 8 samples/chip, this leads to the impulse response with length 63 illustrated on figure 2.

The effect of windowing the impulse response is that the spectrum will no longer be strictly band-limited. It is easy however to calculate the transfer function *G(F)* of the

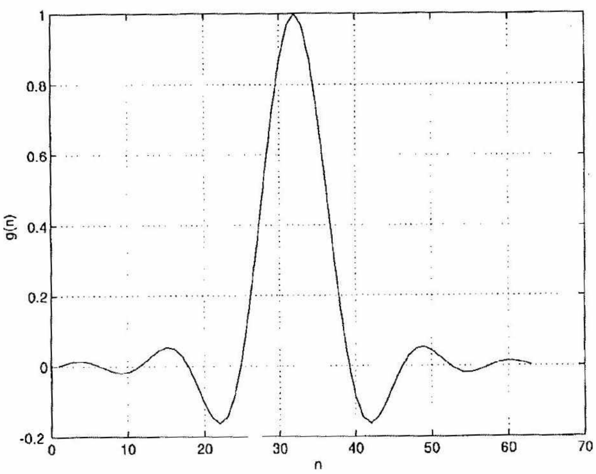

Figure 2 : Impulse response of the actual SRRC filter

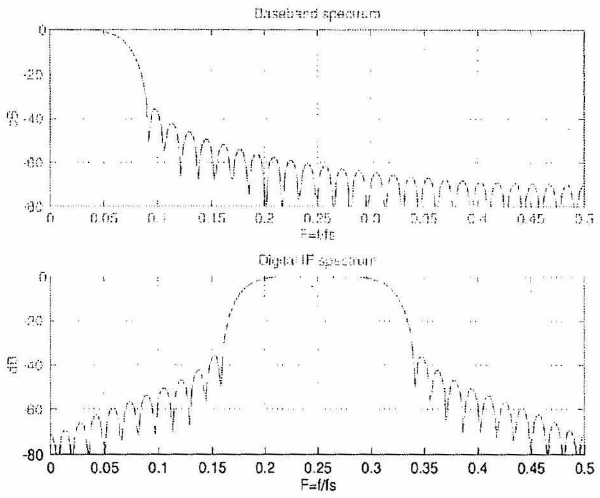

Figure 3 : Spectra of sequences in the digital modem

actual SRRC filter by fast Fourier transform techniques. The power spectra of sequences $v_I(n)$, $v_Q(n)$ as well as of the complex amplitude $v_I(n) - jv_Q(n)$ are all proportional to $|G(F)|^2$ which is illustrated of the top part of figure 3.

Similarly, the power spectrum $S_s(F)$ of the digital IF signal $s(n)$ is given by

$$S_s(F) = \left(|G(F-0.25)|^2 + |G(F+0.25)|^2\right) \qquad (2)$$

and is shown on the bottom part of the figure. The intermediate frequency $2f_c$ indeed corresponds to $F = 0.25$. The spectrum sidelobes are due to the windowing of the theoretical impulse response.

4. Spectrum of the analog IF signals

Let us now investigate the spectrum of the analog IF signals, beginning with the output of the digital to analog converter. Remember that the spectrum of the sequence $s(n)$ is the same as that of the analog pulse train $s_\delta(t) = \sum s(n)\delta(t - nT_s)$ where $T_s = 1/f_s = 1/(8f_c)$ is the sample period. Current digital to analog converters produce a signal which is maintained at the value $s(n)$ during the time interval $[nT_s, (n+1)T_s]$. This signal could be obtained by passing the theoretical pulse train $s_\delta(t)$ through a filter with impulse response $\mathrm{Rect}_{T_s}(t)$, i.e. with transfer function $\mathrm{sinc}(f/f_s) = \sin(\pi f/f_s)/(\pi f/f_s)$. As a result the power spectral density of the signal at the output of the analog to digital converter is obtained by repeating the spectrum $S_s(f/f_s)$ (including negative frequencies) at all multiples of $f_s = 8f_c$ and multiplying the result by $\mathrm{sinc}^2(f/f_s)$.

The power spectral density at the output of the digital to analog converter is illustrated on figure 4. Replicas of $S(f/f_s)$ thus appear at the real frequencies $(2f_c, 6f_c 10f_c, \mathrm{L})$ with progressive damping due to the sinc function. It is clear that the function of the low pass filter following the converter is to further attenuate the replicas at $(6f_c, 10f_c, \mathrm{L})$. The specification of this filter will be discussed later.

Assuming that the conversion to the second IF uses a local oscillator at (70 MHz - $2f_c$), the spectrum shown on figure 4 is shifted by this quantity, negative frequencies included. It is seen that the main lobe at frequency $2f_c$ is transposed at the sum frequency 70 MHz, but also at the difference frequency (70 MHz - $4f_c$). It is the role of the SAW filter to eliminate this spectrum at the difference frequency, but also all residues of the aliased spectra. Assuming that the frequency of the local oscillator for the transfer to the final frequency will be lower than the latter, the side lobe likely to cause interference on the radioastronomy band at 406.1-410 MHz is the one close to 6 MHz on figure 4.

SAW filters at 70 MHz with excellent characteristics are presently commercially available. The filter used in the IRIS design has a 3 dB bandwidth of 0.9 MHz and shows an attenuation larger than 65 dB at frequencies spaced by more than 2 MHz from the center frequency. These 65 dB come in addition to the 15 dB due to the DAC sinc function (see fig. 4) and to the attenuation of the low pass filter. It is seen that the 76 dB attenuation required to protect the RAS bands according to ITU-R Rec. 769 is attainded even without a lowpass filter. In addition, further attenuation will be provided by the radio frequency duplexer.

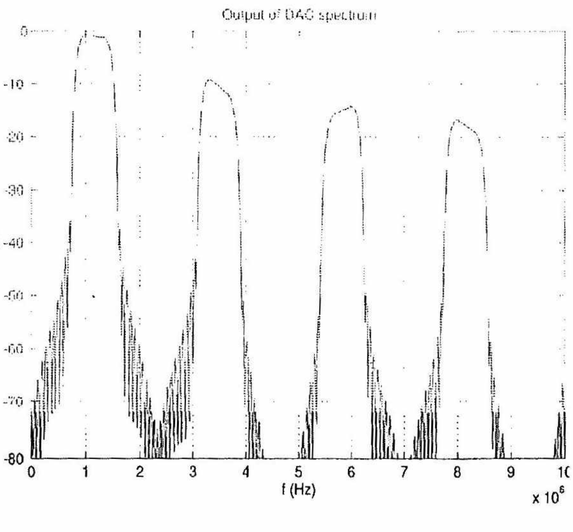

Figure 4 : Power spectral density at the output of the digital to analog converter.

5. Effect of non-linearity in the power amplifier

It has been shown above that the spectrum shaping is such that out of band radiation into the RAS bands will normally be well below the harmful level. However, there is a risk that this nice result be destroyed by some spectral broadening due to the non-linear operation of the class C power amplifier. We want to investigate this rather difficult question into some detail.

5.1. Techno-economical considerations

The power efficiency of the output power amplifier is a critical parameter in the design of a satellite transmitter. The power efficiency is defined as $\nu = P_o / P_s$, where P_o is the useful output RF power and P_s is the supply power. Solar cells are the primary power source in satellite transmitters. As this power is not available during solar eclipse conditions, the solar cells are backed by a battery. The area of solar cells and the battery capacity are directly related to the supply power P_s, which is in turn related to the useful RF power by $P_s = P_o / \nu$. It is immediately seen that, for a given output power P_o, the cost of solar cells and of the backing battery is roughly inversely proportional to the power efficiency. In addition the weight of these elements and therefore the satellite launching cost is strongly related to relevant parameters.

On the other hand, the supplied power which is not transformed into useful RF power is dissipated as heath in the active elements of the power amplifier, i.e. transistors or tubes. The cost of these active elements and of the thermal regulation systems is directly related to the dissipated power, given by $P_d = (1-\nu)P_o / \nu$. It is again roughly inversely proportional to the power efficiency, at least in the area of large efficiencies.

It is seen that some major cost items of a satellite transmitter are directly related to the inverse of the power efficiency of the power amplifier. In the frequency bands considered in this exercise, power amplifiers are based on transistors.

Transistors can be operated in three different modes referred to as classes A, B and C. This classification is based on the concept of conduction angle, which refers to 2π as the period of an applied sine wave ; the parameter used in the description of the internal working of active elements is the half conduction angle θ. In class A amplifiers, the transistors are operated in their linear domain, i.e. they are conducting during the full period of an applied sine wave. The half conduction angle is hereby $\theta = \pi$. In a class B amplifier, the transistors are conducting during one half of the period, and the half conduction angle is $\theta = \pi / 2$. In class~C amplifiers the conductors operate in the conducting mode during less than half of the period, i.e. $\theta < \pi / 2$. It is shown in elementary courses on RF power amplifiers that the upper bound of the power efficiency is :

- 25 per cent for class A amplifiers,
- 50 per cent for class B amplifiers,
- more than 50 per cent for class C amplifiers.

For the latter the power efficiency increases when the half conduction angle decreases. It may typically reach 70 per cent for a well designed amplifier.

There is an obvious interest in using a class C amplifier as the output stage of a satellite transmitter and in operating this amplifier in the range of small half conducting angles θ.

5.2. Some goals in the design of a class C amplifier

A class C amplifier can be seen as a black box driven by an input signal

$$x(t) = a_x \cos(\omega_0 t + \phi_x) \tag{3}$$

This black box contains highly non-linear elements but also filters. The response of a non-linear device to a periodic input is obviously itself periodic. All internal variables describing the device under sinusoidal input can therefore be represented by Fourier series. The role of the filters contained in the black box is to select the fundamental of some internal variable to produce an output signal of the type

$$y(t) = a_y \cos(\omega_0 t + \phi_y) \tag{4}$$

Quite generally the pair of output variables (a_y, ϕ_y) can depend on the input pair (a_x, ϕ_x). Most frequently however, the characteristics of class~C amplifiers is such that there is no phase effect, i.e. $\phi_y = \phi_x$ and a_y doesnot depend on ϕ_x. In these conditions the behaviour of the class C amplifier can be described by the non-linear relation $a_y = f(a_x)$. Alternatively one can use the amplifier gain characteristic $G = a_y / a_x$. The difference between a class C amplifier and a linear (class A) amplifier hereby reduces to the fact that the gain G depends on the input amplitude a_x. It is already understood that the gain characteristic $G(a_x)$ fully describes the macroscopic behaviour of a class C amplifier.

When the input is a narrow-band modulated signal rather than a pure sine wave, this model can still be used. However a_x and ϕ_x are now slowly varying functions of time. Thus the response to

$$x(t) = a_x(t)\cos[\omega_0 t + \phi_x(t)] \tag{5}$$

is given by

$$\begin{aligned} y(t) &= a_y(t)\cos[\omega_0 t + \phi_x(t)] \\ &= a_x(t)G[a_x(t)]\cos[\omega_0 t + \phi_x(t)] \end{aligned} \tag{6}$$

It is generally stated that the non linear behaviour of a class C amplifier does not affect the output signal for an input $x(t)$ which results of a constant envelope modulation. Some analysis of this statement is instructive. The internal working of a class C amplifier is such that the gain G depends on the half conduction angle θ, which is in turn a function of the input amplitude a_x. Driving the amplifier with a constant amplitude modulation signal would indeed mean that the gain is constant and that the macroscopic behaviour of the amplifier is the same as for a class A amplifier. These observations have the merit to indicate some objectives in the design of a class C amplifier for non-constant envelope modulations. In this case, the instantaneous amplitude a_x is allowed to fluctuate in some domain. The ideal design of the amplifier is such that the half conducting angle $\theta(a_x)$ would remain constant over this domain. On the other hand the target value of θ in this design should be as small as possible in order to get a high power efficiency.

5.3. Model of a class C amplifier

Our objective here is not to design a class C amplifier, but rather to identify what could be the gain characteristic $G(a_x)$ for a well designed amplifier, in relation with the modulation actually used in the IRIS satellite system. We are therefore interested in the analysis of a simple circuit which exhibits the typical behaviour of a class C amplifier. Such a circuit is illustrated on figure 5.

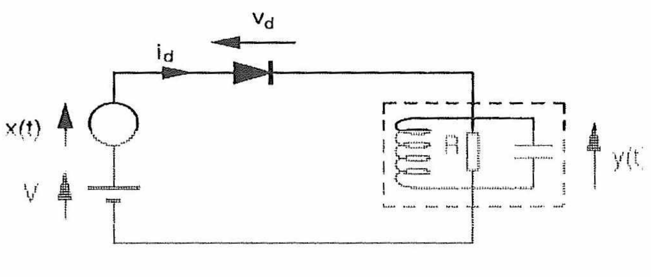

Figure 5 : A simple circuit with the typical behaviour of a class C amplifier

The circuit includes a negative polarisation source V, the purpose of which is to block the diode in the non-conducting state in the absence of a useful signal $x(t)$ with amplitude V_x. The load is represented by a resonant circuit. How this circuit is implemented does not matter. The important fact is that it is supposed to have a resistive impedance R at frequencies in the vicinity of the carrier ω_0 and a virtually null impedance at all other frequencies, i.e. at DC and harmonics $n\omega_0$. The output voltage $y(t)$ is therefore sinusoidal, with some amplitude V_y, although the diode current $i_d(t)$ is essentially impulsive.

Figure 6 illustrates the voltages and the current in this typical circuit. When the sum $(V + x)$ exceeds y, the diode enters into conduction. As the input amplitude V_t increases, so does the conduction angle θ. However, the current impulse hereby increases and, as the output amplitude V_y is given by the product of the fundamental of $i_d(t)$ by the dynamic resistance R, it also grows. The increase of the conduction angle is hereby slowed down. The unknowns of the problem are the half conduction angle θ and the output amplitude V_y. The problem can be solved when a model of the diode is known. The simplest model is the bilinear one, where the diode conducts above some threshold voltage V_t, i.e. for $v_d > V_t$ and has some resistance ρ in the conducting state. The current impulse is then a clipped cosine for which it is easy to develop the Fourier series expansion. Writing the loop voltage equations, one obtains the following two equations

$$V_y = \frac{R}{\pi\rho}\left(V_x - V_y\right)(\theta - \sin\theta\cos\theta) \quad (7)$$

$$V_t = V + \left(V_x - V_y\right)\cos\theta \quad (8)$$

These equations can be solved numerically in the two unknowns of the problem, which are the half conduction angle θ and the output amplitude V_y. The diode threshold

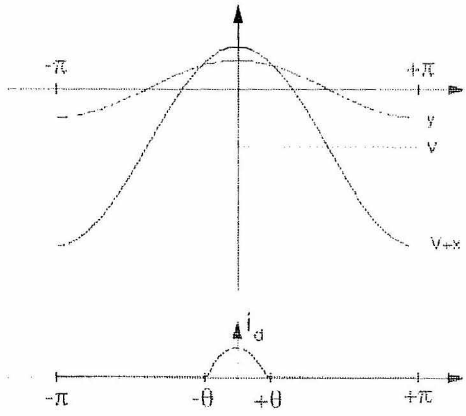

Figure 6 : Voltages and current in the model of a class C amplifier

voltage V_t actually acts as a scaling factor and its value was frozen to 0.7 volt, which is the threshold voltage of a silicium diode. The equations contains two parameters, namely the polarisation voltage V and the ratio $P = R/(\pi\rho)$. These parameters can be adjusted to obtain a good representation of a well-designed class C amplifier for the application under consideration.

Figures 7 and 8 show the results of some calculations. Clearly the diode remains blocked as long as the input amplitude V_x is smaller than $|V| + V_t = 1.7$ volt. The behaviour of the conduction angle and of the gain above this cutoff amplitude strongly depends on the parameter P. This parameter should be adjusted to obtain a good representation of a well-designed class C amplifier for the application under consideration. There are two requirements to be met on the dynamic range of the instantaneous amplitude $V_x(t)$. The conduction angle should remain small enough to reach a high power efficiency and the gain $G(V_x)$ should be as constant as possible.

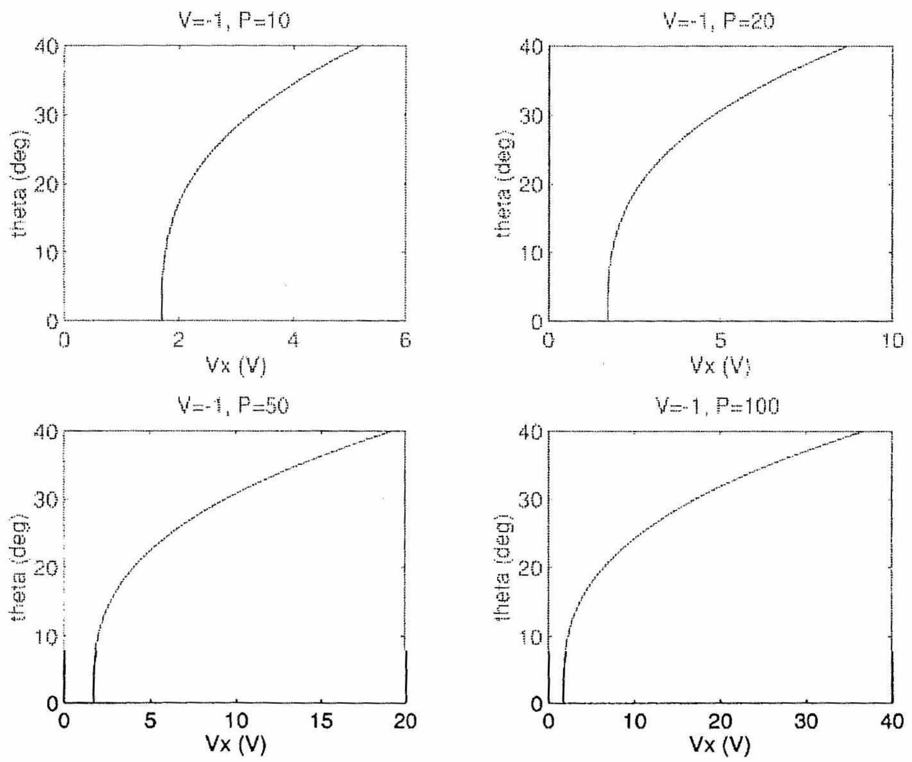

Figure 7 : The half conduction angle as a function of the input amplitude V_x for a polarisation voltage V = -1 volt and different values of the parameter P.

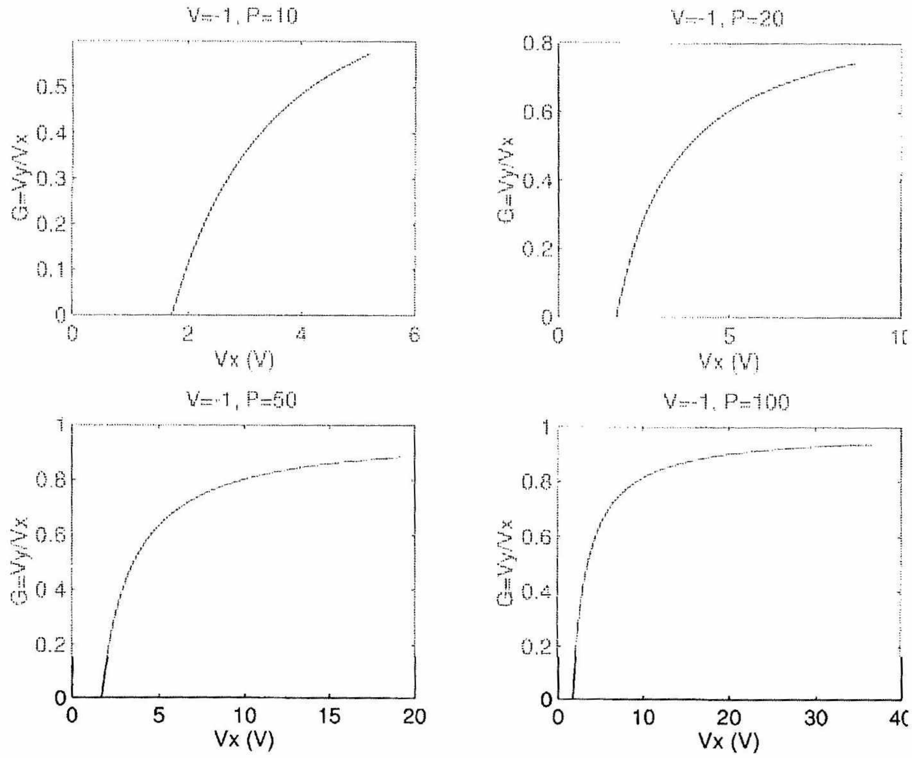

Figure 8 : The gain $G=V_y/V_x$ as a function of the input amplitude V_x for a polarisation voltage V = -1 volt and different values of the parameter P.

5.4. Model selection and spectrum estimation

In order to select the parameters for a reasonable model of a class C amplifier, it is necessary to know the dynamic range of the instantaneous amplitude for the offset QPSK modulation actually used in the IRIS satellite design. The complex envelope $e_x(t) = a_x(t)\exp[j\phi_x(t)]$ of such a signal was therefore generated. As a matter of fact, as spectrum shaping was quite efficient, we may consider that $e_x(t)$ is well represented by the sequence $v_I(n) - jv_Q(n)$ defined on figure 1. The result is illustrated on figure 9 for a signal duration of 100 chips.

This figure calls for some comments. It is seen that, at least with the type of Nyquist filter used, the OQPSK modulation somewhat departs from a constant envelope modulation, which is ideal regarding the non-linear effects of a class C amplifier. Should a rectangular pulse shape have been used, then the complex envelope would have jumped instantaneously at the half chip rate between the nominal values $(\pm 1 \pm j)$. Any transition would be allowed for non-offset QPSK, whereas for OQPSK only transitions along the sides of nominal square can occur. A modulation similar to OQPSK where the transitions would occur at constant speed along the unit circle is known as MSK (minimum shift keying). The drawback of MSK is however that the signal is not band-limited. To some extent, it can be stated that a non-constant amplitude is the price to be paid for a strictly band-limited signal $x(t)$.

Whatever the arguments which could be invoked in such a discussion, simulations of the type shown on figure 9 performed over quite long time intervals show that, for the IRIS design, the normalized instantaneous amplitude fluctuates in the interval $0.59 < a_x(t) < 1.83$. The dynamic range to be assumed by the class C amplifier is hereby $a_{x,\max} / a_{x,\min} = 3.1$. As can be seen on figures 7 and 8, the class C amplifier model developed in the previous section cannot meet the design requirements (small θ, constant G) for small values of the design parameter P. For simulation purposes the value $P = 100$ was assumed (fourth quarter of figures 7 and 8) as well as a scaling factor such that the dynamic range $0.59 < a_x(t) < 1.83$ be mapped in the interval $9.2 < V_x < 28.6$ volt. To some extent, these choices are similar to the decisions a design engineer has to make in the selection of a class C amplifier.

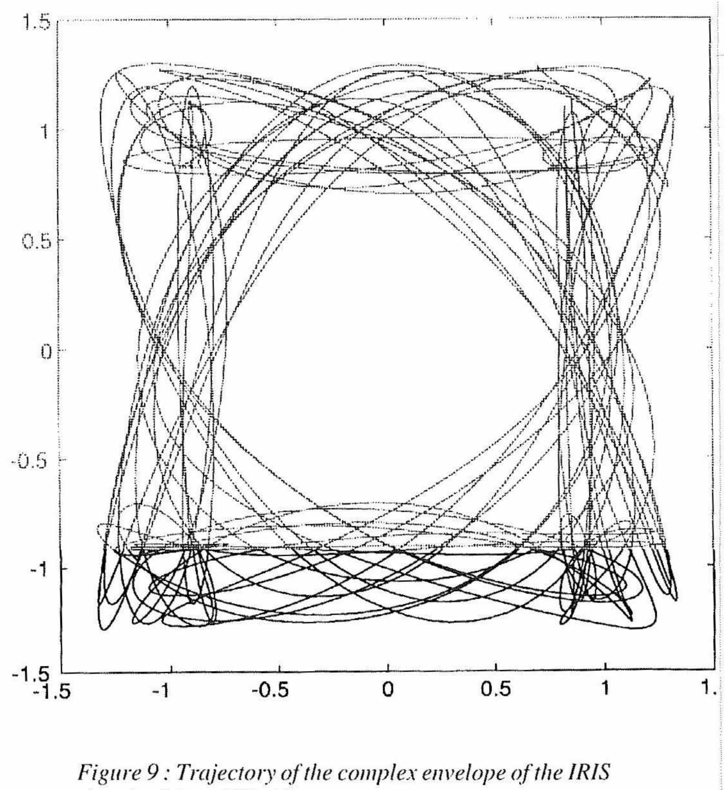

Figure 9 : Trajectory of the complex envelope of the IRIS signal $e_x(t)$ on 100 chips.

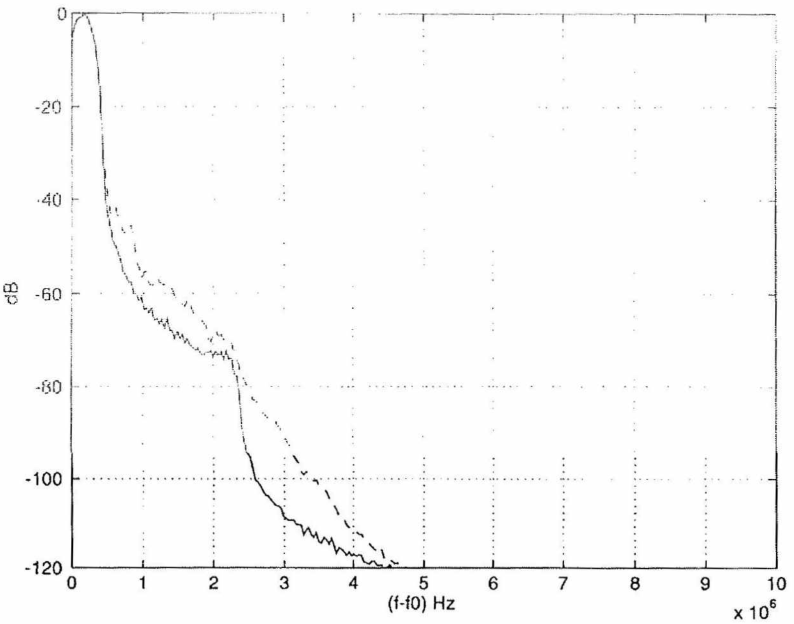

Figure 10 : Power spectral densities at the input (full line) and output (broken line) of the class C amplifier.

This being done, it becomes a rather straightforward task to estimate the out-of-band radiation due to the non linear behaviour of the power amplifier, using existing software packages such as MATLAB and its Signal Processing Toolbox. First, the gain characteristic $G(a_x)$ is fitted by a polynomial approximation. Then a sequence of the complex envelope $e_x(n) = a_x(n)\exp[j\phi_x(n)]$ is generated and the complex envelope $e_y(n) = a_x(n)G[a_x(n)]\exp[j\phi_x(n)]$ is calculated. Finally the power spectral densities of $e_x(n)$ and $e_y(n)$ are estimated using Welch's method implemented in the MATLAB routine psd.m.

Figure 10 shows the result of such a calculation. Welch's spectrum estimation method [2] allows the user to select a number of parameters which control the frequency resolution, the dynamic range and the accuracy of the result. The spectra showed on figure 10 were obtained with a sequence length of 1000 chips, 32 samples/chip, a FFT order of 256 and a hanning window. The use of 32 samples/chip was necessary in order to estimate spectra at frequencies spaced by up to $16f_c$ (i.e. about 8MHz) from the carrier. The spectra at the input and output of the class C amplifier, normalized to their peak value, are illustrated by the solid and broken lines, respectively. The abscissa is the difference $(f - f_0)$, where f_0 is the carrier frequency.

It is seen that the non-linearity of the class C amplifier results into some out-of-band radiation. The effect is very weak and is limited to the immediate neighbourhood of the main lobe. It will not cause any noticeable interference in the RAS bands. In addition, out-of-band radiation if any would be further reduced by the filters contained in the transmit-receive duplexer. Simulations using actual characteristics of well-designed class C amplifiers have confirmed this conclusion.

6. Conclusions

Some quite interesting conclusions can be made from this case study. It is certainly useful to know that the projected satellite will not cause harmful interference to RAS systems.

More important maybe is the observation that the power spectral density of spread spectrum signals can be perfectly confined in a nominal bandwidth which is of the order of $1.5f_c$ where f_c is the chip rate. Accurate spectrum shaping can be obtained through modern digital signal processing techniques acting at the baseband level on spread spectrum signals, combined with performant analog filtering elements such as surface acoustic wave filters operating at intermediate frequency. In the present case, the whole transmitter is embarked in the satellite, but similar spectrum shaping techniques can be used in terrestrial transmitters for relaying by classical transparent satellite transponders. These techniques are rather cheap. They are probably much cheaper than the RF filters that would be needed when spectrum spreading is performed at the RF level, a non-recommended approach.

Whereas spectrum shaping techniques are well known and are state of the art, a much more delicate question is spectrum broadening in power amplifiers exhibiting non-linear characteristics such as class C amplifiers or travelling wave tubes. The methodology developed above provides a quite useful approach to this type of problem. It gives much insight on the influence of the transfer characteristic of non-linear devices on spectrum broadening. On the other hand, it clearly puts in evidence the interest of nearly constant envelope modulations. Offset QPSK is undoubtedly a good choice in this respect, provided the class C amplifier exhibits nearly constant gain for a dynamic range of input voltage of 3/1, i.e. 9/1 for power in the case under study. To illustrate this statement, let us mention that the simulation programs developed for this case study have been ran for non-offset QPSK. In this case, the harmful interference level in RAS bands is reached, at least in the absence of filtering in the output duplexer (the psd -dotted line- on fig. 10 would be about -60 dB for QPSK). This is the result of very strong non-linearity in the transfer characteristic of the class C amplifier, which is abruptly cutoff for small amplitudes.

References

[1] J.G. PROAKIS, Digital Communications, McGraw-Hill, 1989.

[2] A.V. OPPENHEIM and R.W. SCHAFER, Discrete-Time Signal Processing, Prentice-Hall, 1989.

Lille General Assembly 1996

SCIENTIFIC PROGRAMME - LILLE G.A. 1996

As convenors of the Commission B Session B9 "Electromagnetic Theory" at the URSI General Assembly in Lille,France,August 28-September 5,1996, we would like to announce that we plan to have this session focused on the theme of

TIME-DOMAIN VS FREQUENCY DOMAIN METHODS IN ELECTROMAGNETIC THEORY

The session will consist of both invited and contributed papers.Thus,papers which discuss the pros and cons of the two approaches in both forward and inverse scattering and propagation problems are particularly welcome.

Please note that the deadline for contributed papers is **January 8,1996**.

Sincerely yours,

Peter van den Berg
Staffan Strom
e-mail: staffan@tet.kth.se

Conferences

CONFERENCE REPORTS

INTERNATIONAL CONFERENCE ON COMPUTATIONAL ELECTROMAGNETICS AND ITS APPLICATIONS (ICCEA'94)

Beijing, China, 1-4 November, 1994

The first International Conference on Computational Electromagnetics and its Applications (ICCEA'94) was sponsored by the China Institute of Electronics and IEEE Beijing Section, and the International Union of Radio Science, in cooperation with IEEE/AP-S and MTT-S. ICCEA'94 was held on 1 - 4 November in Beijing, China.

Professor Wei-Gan Lin from the University of Electronic Science and Technology, China, was the General Chairman of the conference committee and Dr. W. Ross Stone from the U.S.A. was General Co-Chairman.

The scientific programme committee was chaired by Professor Shi-Zhi Li from the Beijing Institute of Technology.

Following the plenary session of opening addresses, there were four invited papers presented by Dr. W. Ross Stone (U.S.A.), Prof. Shi-Zi Li (China), Dr. F. Mariotte (France) and Prof. Wen-Xun Zhang (China) in sequence. Then two parallel sessions were arranged with the following subjects : method of moments, finite difference-time domain method, finite element method, geometric/uniform theory of diffraction, other methods, theoretical electromagnetics, electromagnetic field in complex media, non-linear electromagnetic wave, electromagnetic scattering, antennas, optical fibres, inverse scattering & microwave imaging, microwave integrated circuit & monolithic MIC, electromagnetic compatibility & subsurface radar.

The Proceedings were pre-printed by the Publishing House of Electronic Industry (Beijing, China) and collect 139 accepted full papers with contributions from Australia, Bulgaria, Canada, China, Finland, France, Germany, India, Italy, Japan, Korea, Portugal, Russia, Switzerland, Turkey, the United Kingdom and the U.S.A.

The conference was attended by 136 participants from 30 countries, who exchanged technical information and held deep discussions during the conference.

Prof. Wen-Xun Zhang
Official Member, Commission B
China CIE (Beijing)

Radio Emission from the Stars and the Sun

Barcelona, Spain, 3 - 7 July, 1995

In the earliest days of radio astronomy, compact cosmic radio sources were often referred to as "radio stars" although the vast majority were subsequently revealed to be extragalactic in origin. With the advent of sensitive interferometric arrays in the 70s and early 80s, however, bona fide stellar objects were detected, and by the mid-80s, the study of radio emission from stars was a burgeoning new field of study.

The first meeting devoted to the subject of radio emission from stars occurred ten years ago ("Radio Stars", Boulder, CO, 1984) and addressed stellar winds, active binaries and flare stars, high energy phenomena, and theoretical issues in a total of 50 invited and contributed papers. Since that time there have been major observational advances in this field. The number of stars and classes of stars that are known to be sources of radio emission has increased dramatically. With continued improvement in VLBI instrumentation and techniques (e.g., the Very Long Baseline Array and the European VLBI Network) it is now possible to image radio emission from stellar sources with an angular resolution and sensitivity that was impossible ten years ago. Moreover, there have been new and exciting results in the millimeter and submillimeter bands from new single dish (e.g., SEST, JCMT, CSO) and interferometric (e.g., BIMA, OVRO, NRO) instruments. These data have revealed new phenomena associated with stars and have yielded new observational data on previously known phenomena. The study of radio emission from stars has thus matured into a broad and vigorous discipline in the roughly two decades since its birth.

The study of radio emission from stars overlaps, in several important respects, with the study of radio emission from the Sun. While solar radiophysics finds its roots in the very earliest days of radio astronomy, it continues to thrive, especially so in recent years. Particularly important have been new instruments and techniques (e.g., the new 17 GHz radioheliograph at Nobeyama, the OVRO frequency agile solar array), the advent of multiwavelength studies of solar phenomena, high resolution spectroscopy of the decimetric wavelength regime, and millimeter wavelength interferometry of active phenomena.

In light of these advances in both stellar and solar radio astronomy an international meeting devoted to the subject is a timely event. While solar and stellar radio astronomers have traditionally worked as two separate communities, given the significant advances in each area, the meeting presented an excellent opportunity to foster cross-fertilization between the two disciplines. Therefore the University of Barcelona hosted an international meeting on "Radio Emission from the Stars and the Sun", attended by more than 120 participants from 20 nations.

The meeting was ambitious in scope but accurately reflected the progress made in the decade since the Boulder meeting. The most recent theoretical and observational developments in the various subdisciplines were reviewed by 25 invited talks and discussed at length in over 100 contributed papers. A brief summary per area follows.

IONIZED ENVELOPES

G. Anglada (Univ. of Barcelona, Spain) reviewed the most recent interferometric observations of radio emission associated with young stellar objects. Multifrequency observations show that the continuum emission at cm wavelengths is predominantly thermal free-free radiation. Observations on the smallest angular scales show that the emission is elongated along the direction of largescale outflows, and in some cases proper motion is seen. These results suggest that "thermal jets" trace out collimated outflows of ionized material. P. Williams (ROE, UK) discussed radioemission by Wolf-Rayet and OB stars. Here, recent observations at mm wavelengths have allowed the determination of spectral indices over larger baselines than was possible in past years. Departures are seen from spectral forms expected from stationary, uniform, isothermal flows, and in some cases nonthermal components are present. High resolution observations of several systems reveal remarkable structure in the radio emission. C. Skinner and collaborators (STSCI, USA) considered the specific case of the P Cygni nebula, the prototypical stellar source displaying an ionized outflow. The emission is again shown to be complex and extended.

NEUTRAL ENVELOPES

Mass loss in the form of cool, dusty molecular winds dominates the late stages of stellar evolution. J. Knapp (Princeton Univ., USA) reviewed the nature of molecules, dust, and structure in these neutral outflows, which can extend out to several parsecs from the star. She showed that stars can evolve to the final white dwarf stage through several different paths: some stars display symmetric outflows of constant speed; others lose mass episodically; others lose mass anisotropically; still others display fast winds with large velocity gradients. K. Menten (CfA, USA) described recent observations of circumstellar masers, emphasizing recent VLBA and single dish submillimeter observations of H2O and SiO masers. M. Reid (CfA, USA) discussed the most recent work on the outer envelopes of Mira variables. In contrast to optical wavelengths, radio light curves of Miras conform to a blackbody spectrum which is nearly independent of time. A model of the Miras was suggested.

SUPERNOVAE

Radio emission from supernovae presents many puzzles. Progress in solving these puzzles is hampered by the rarity of their occurence and the great distance to many of the events which are observed. Nevertheless, the past decade has seen a great deal of progress. On the theoretical front R. Chevalier (Univ. of Virginia, USA) reviewed the evidence that, for some supernovae, the radio emission is due to interaction between the outer part of the supernova with stellar mass lost prior to the explosion. On the observational front, J. Marcaide (Univ. of Valencia, Spain) discussed recent high-resolution VLBI observations of supernovae, while K. Weiler and collaborators (NRL, USA) reviewed interpretations of available radio light curves.

NOVAE AND CATACLYSMIC VARIABLES

The VLBA and MERLIN interferometric arrays have played an important role in clarifying the nature of radio outbursts from novae and recurrent novae. R. Hjellming (NRAO, USA) reviewed multiwavelength radio and optical optical observations of classical novae, three with resolved radio maps. The richest data base is that of Nova Cygni 1992, which allowed detailed modeling to be performed.

Application of a uniform model to nova outbursts was proposed. M. Bode and H. Lloyd (Univ. of Liverpool, UK) presented MERLIN observations of radio emission from both classical and recurrent novae, and discussed their origin and evolution.

X-RAY BINARIES

A recent and spectacular discovery was that of superluminal motion in a galactic radio source. L. Rodriguez (Univ. Nacional Autonoma, Mexico) reviewed the most recent radio observations of hard X-ray binary systems, emphasizing those displaying extended radio jets and superluminal ejecta. With respect to the latter, longterm monitorng of GRS 1915+105 suggests that relativistic electrons are ejected repeatedly and quasiperiodically on an interval of 20—30 days. L. Ball (Univ. Sydney, Australia) reviewed theoretical ideas concerning radio emission from X-ray transients.

RADIO ACTIVITY ON STARS

With the discovery of soft X-ray emission and nonthermal radio emission from the coronae of late-type stars, the general issues of coronal heating and stellar activity have been important problems. B. van den Oord (Utrecht, the Netherlands) reviewed nonthermal emission mechanisms believed to be operating in stellar coronae. M. Guedel discussed the observed correlation between SXR and nonthermal radio emission on the Sun and stars. P. André (CEA/Saclay, France) reviewed recent observations of radio emission from pre-main sequence objects. R. Becker (Univ. Califronia, USA) described preliminary observations of stars in the FIRST 20 cm survey, now in progress at the VLA.

THE ACTIVE SUN

A great deal of recent progres has been made in elucidating the nature of radio emission associated with stellar flares from meter to millimeter wavelengths. Of particular interest has been recent progress in understanding decimetric emissions and their relationship to emissions in other wavelength bands — the hard X-rays for example. A. Benz (ETH, Switzerland) reviewed spectroscopic observations of decimetric emissions obtained with a broadband, digital spectrograph during the last solar maximum period. L. Vlahos (Univ. of Thessaloniki, Greece) considered how these, and other radio bursts, could be described in terms of global models of solar activity.

THE QUIET SUN

While the emission mechanisms associated with radio emission from the quiet Sun are well-understood (H and H-minus free-free), there are difficulties in reconciling radio emission with UV and EUV line observations which increase in severity with increasing radio wavelength. D. Gary (Caltech, USA) reviewed the current state of radio observational work on the nonflaring Sun, and prospects for reaching an understanding of the Sun's lower atmosphere using radio and UV observations.

RESULTS FROM NEW INSTRUMENTS

A number of new and upgraded instruments have come online in recent years which are designed for solar applications. S. Enome (NRO, Japan) described the new 84 element 17 GHz radioheliograph at Nobeyama, and presented several observations of solar flares. D. Gary (Caltech, USA) described the recently upgraded OVRO Solar Array, comprised of two 25 m antennas, and three 2 m antennas, each frequency agile between 1—18 GHz. A number of examples of broadband imaging spectroscopy were presented. G. Gelfreikh (RATAN 600, Russia) presented a number of examples of spectral polarization observations of solar active regions using the upgraded RATAN 600 telescope.

THE STELLAR/SOLAR CONNECTION

The problem of radio emission from the Sun and stars was considered in a final session. J. Linsky (Univ. of Colorado, USA) reviewed plausible emission mechanisms responsible for quiescent radio emission from the Sun and stars and suggested a scenario by which the observed correlation between coronal SXR and nonthermal radio emission might be understood. T. Bastian (NRAO, USA) discussed radio flares on the Sun, classical flare stars, active binaries, and pre-main sequence objects, showing that stellar flares differ in important respects from those on the Sun. The possible role of induced scattering and eruptive processes was pointed out.

In summary, the Barcelona meeting achieved its goal of bringing together a large and diverse community of workers in the fields of stellar and solar radio astronomy. All benefited from exposure to the broad program of science presented, and the many informal discussions which occured during the course of the week produced the desired cross-fertilization between the many subdisciplines. What was quite clear from the presentations was this: that while stellar radio astronomy has matured significantly over the past decade, the best is yet to come. Many upgraded or recently completed instruments are only now being exploited. Many more upgrades and new instruments are being planned. Clearly, stellar and solar radio astronomy will remain exciting for many more years.

Biophysical Aspects of Coherence

Prague, Czech Republic, 11 - 15 September 1995

The Biophysical Aspects of Coherence conference was held in Prague, Czech Republic from 11 to 15 September, and was organised by the Faculty of Mathematics and Physics of Charles University in Prague.

There were 72 participants, including six supported Young Scientists and three students. The attendees came from 21 different countries.

The Workshop included plenary review lectures, oral presentations and posters which contributed to comprehensive presentation of the state of art of the biophysical aspects of coherence, mechanics of coherent states in biological systems and their interaction with electromagnetic fields.

The invited lectures have been published in a special issue of the journal "Neural Network World".

The Fröhlich memorial lecture was presented by Professor G.J. Hyland of the United Kingdom and followed by a concert.

Jan Musil
Official Member, Commission K

Second URSI International Workshop for Working Group AFG1

Remote Sensing and Atmospheric Research Using Radio Occultation Techniques with the Global Navigational System

Tucson, Arizona, February 22-23, 1996

The Global Positioning System (GPS) is an advanced satellite navigation system offering precision global services. The system includes a constellation of 24 operational satellites and an extensive ground control system operated by the US Air Force. GLONASS, a Russian satellite navigation system similar to GPS, is now approaching operational status as well. Although these systems were developed primarily for military needs, numerous scientific and commercial applications have matured in parallel, and new applications are growing rapidly. It now appears the Global Navigation System (GNS) is destined to become a global utility upon which many manufacturing and service industries will rely.

Remote Sensing of the Earth's atmosphere and ionosphere using the radio occultation technique has now been demonstrated using observations from GPS/MET, an experimental GPS receive-base- instrument launched April 3, 1995, aboard the MicroLab-1 satellite. Using this dual frequency active limb sounding technique, high accuracy profiles in the neutral atmosphere of refractivity, density, temperature, pressure and relative humidity may be obtained from near the surface to 50 km or more. In the ionosphere, imaging of electron density distribution using GNS signals appears promising.

In June 1995, the first meeting of URSI Working Group AFG1 was held in Copenhagen, Denmark, to discuss this exciting new method of Earth remote sensing and its applications. Since then, progress in the field has been brisk. This second meeting of Working Group AFG1 will continue to focus on the technical and scientific aspects of space-based observations of the navigation signals transmitted by GNS satellites. Special emphasis will be devoted to data analysis and recovery of atmospheric and ionospheric parameters from GPS/MET observations.

This two day workshop will be hosted by the Department of Atmospheric Sciences, University of Arizona, Tucson, Arizona.

Topics

I. Systems Topics GPS and GLONASS receiver based instruments, high-gain occultation antennas, host satellites for LEO receivers, orbits and coverage, constellations, fiducials and clocks, optimizing ground data networks and processing systems, and system performance vs. economics tradeoffs.

II. Orbit Determination and System Calibration Precision Orbit Determination (POD) requirements and methods, Double Difference (DD) processing strategies, fiducial receiver elevation mask selection, clock (reference) satellite selection criteria for DD processing, impact of and strategies to minimize neutral atmospheric errors due to ionospheric bending, impact of and strategies to minimize Selective Availability and Antispoofing related errors, and data smoothing/filtering algorithms.

III. Neutral Atmosphere Retrieval Methods and Issues Bending angle determination, fast 3D ray tracing, Abelian and other methods used to recover refractivity, retrieval techniques for atmospheric density, pressure, temperature, turbulence, waves and tropospheric moisture, diffraction effects and recovery of anomalous propagation maps.

IV. Ionospheric Retrieval Methods and Issues Recovery of Total Electron Content (TEC), global distribution of ionospheric electron density, Traveling Ionospheric Disturbances (TIDs) and waves, and related phenomena.

V. Higher Level Processing Four Dimensional Variational Data Assimilation (4DVDA) for numerical weather prediction, tomographic techniques and other ways to combine radio occultation observations with conventional space and ground based observations for improved weather forecasting and global real-time ionospheric electron distribution mapping.

VI. System Errors, Analysis, and Validation Theoretical analysis of generic and planned GNS based observing systems, error sources and minimization, GPS/MET data analysis and validation, WakeShield data analysis and validation.

VII. Radio Occultation Science and Applications Space physics research, radio wave propagation in and through the ionosphere, Earth gravity field monitoring and change, applying GPS/MET experience to future planetary radio occultation experiments, weather forecasting, climate change research, space weather.

For further information, please contact :

Dawn Hibble
Department of Atmospheric Sciences
University of Arizona
PAS Bldg. 81, Room 542
Tucson, AZ 85721, USA
fax : 1-520-621-6833
Email: dawn@air.atmo.arizona.edu

EUSAR 1996

Königswinter, Germany, 26-28 March, 1996

The First European Conference on Synthetic Aperture Radar will be held on 26-28 March 1996 in the MARITIM hotel Königswinter in the pittoresque Rhine valley. It is organized by FGAN (German Defence Research Laboratory), DLR (German Aerospace Reseach Establishment), and VDE (The German Institute of Electrical Engineers), and is co-sponsored by EUREL, URSI, IEEE and DGON.

Background

SAR has grown so dramatically in the recent past, particularly through advances in computing power and microwave technology that it has become a discipline independent of real aperture radar. SAR is no longer adequately covered by the traditional international Radar Conferences. The existing conferences on remote sensing are devoted mainly to SAR applications rather than to SAR techniques and technologies. The gap between radar and remote sensing conferences will be filled by EUSAR'96 and its follow-up events.

Participants

20 European and non-European countries from 5 continents, and 4 international organisations contributed to the EUSAR'96 program. It includes 86 oral and 57 poster papers carefully selected by the International Scientific Committee. All papers will be published in the EUSAR conference proceedings.

Side attractions

A small industrial exhibition presenting the state of the art in SAR technogy will be held. In addition to the conference volume the March 1996 issue of AE (International Journal of Electronics and Communication, Germany) will be devoted to EUSAR'96. Here a limited number of selected papers will be published in more detailed form, giving a representative overview of the present state of the art in SAR techniques and technology and, at the same time, of the SAR activities in the various countries.

Technical Program

The technical program of EUSAR'96 reflects current trends in synthetic aperture radar. The central problem is image generation and evaluation. While some years ago topics such as platform motion compensation and autofocus were considered the most urgent problems now a strong trend towards interferometric SAR can be noticed. Also lively interest in detection and imaging of moving targets is coming up. The EUSAR'96 Technical Program is subdivided in the following sessions:

- Plenary session including keynote speeches and overview papers
- Air- and Spaceborne Systems
- Image Enhancement and Evaluation
- Polarization
- Interferometry
- Antennas and T/R Modules
- Image Generation
- Processing and Simulation
- Moving Targets
- Applications
- Calibration

The conference will be opened by four distinguished speakers, two from Germany and two from international organisations. The civilian and military sides are both covered. Subsequently the plenary session continues with overview papers by two leading SAR experts. EUSAR will be the European forum for the worldwide SAR community to exchange experience, to represent the state of the art and to open prospectives for the future.

For detailed information, please contact :

the chairman :

R. Klemm, FGAN-FFM
Neuenahrerstr. 20, D-53343 Wachtberg, Germany
Tel. +49 228 9435 377
Fax. +49 228 348 953
Email rklemm@elserv.ffm.fgan.de

CLIMPARA'96

Oslo, Norway, 10-11 June 1996

Climpara is the URSI Commission F Workshop on Climatic Parameters in Radiowave Propagation Prediction.

Climpara'94 was a special-interest URSI Commission F Open Symposium held in Moscow on 31 May-3 June 1994. It included: invited keynote presentations, offered research presentations, workshop sessions and a poster session (see URSI Radioscientist and Bulletin, September 1994, p. 8-9). To some extent it followed the pattern of the URSI Commission F Special Open Symposium held in Rio de Janeiro in December 1990, on a similar theme. This was followed immediately by concurrent meetings of those closely associated with these issues in two Working Parties of ITU-R. This arrangement enhanced the exchange of ideas and information on this topic between the two communities. In the same way, ITU-R WPs 3J and 3M (who are now responsible for fundamentals and application of this work) are holding parallel meetings in Oslo on 12-18 June 1996. It is to be expected that some who attend the URSI meeting will also attend the ITU-R meeting, and vice versa. However, the URSI-sponsored meeting is intended to concentrate on radio science aspects of the work and not the development of prediction procedures.

Rather than have many research contributions, such as were presented at Rio, at Moscow and in the URSI Commission F triennial Open Symposia, etc, the present Call for Papers invites two types of presentation:

i) Reviews of personal contributions to the topic areas in recent years (20 minutes), with comments on the main features of papers produced (and references)
ii) Recent research contributions (10 minutes).

Submission deadline : 16 February 1996.

Topics :

- **Clear air** - modelling and climatic parameters needed, data available, measurements still needed, instruments.
- **Precipitation** - modelling and climatic parameters needed, data available, measurements still needed, instruments.
- **Mapping procedures.**

The workshop will be hosted by Telenor and the Norwegian Telecommunications Authority.

For further information, please contact :

the Chairman of the Scientific Programme Committee :

Mr M P M Hall
CLIMPARA'96
Rutherford Appleton Laboratory
Chilton, Didcot, Oxon OX11 OQX
United Kingdom
Phone : +44 1235 446650
E-mail : Martin.Hall@ rl.ac.uk.

PIERS 1996

Innsbruck, Austria, 8 - 12 July 1996

The Progress in Electromagnetics Research Symposium (PIERS 1996) will be held on 8-12 July, 1996, at the Congress Center, Innsbruck, Austria.

PIERS provides an international forum for reporting progress and recent advances in the modern development of electromagnetic theory and its new and exciting applications. Suggested topics are listed below, but consideration will be given to papers on other subjects. PIERS 1996 is organized jointly by University of Innsbruck, Institute of Meteorology and Geophysics, Tyrol Congress GMBH, Congress Innsbruck GMBH

Topics

Electromagnetic theory, Electromagnetic properties of natural media, Electromagnetic wave nteraction with natural media, Scattering and emission of land, ocean, and ice, Inverse scattering problems, Wavelets in electromagnetics, Experimental validation of scattering models, Polarimetric theory and applications, Remote sensing of the atmosphere (optical to microwaves), Radar meteorology, Remote sensing of vegetation: techniques and inversion algorithms, Interferometry, Geophysical sub-surface sensing, Wave propagation in atmosphere and ionosphere, Computational electromagnetics: methods and applications, Nonlinear media, Signal processing, Guided waves, Biomedical effects and applications, Classification techniques and parameter retrieval algorithms, Antennas: theory and measurements; active and phased arrays, Microwave radiometers: techniques, measurements and applications.

Advance Program will be mailed by April 15, 1996. Registration, lodging and local information will be mailed with the Advance Program.

For more information, please contact :

PIERS 1996
Institute of Meteorology and Geophysics
University of Innsbruck
Innrain 52, A-6020 Innsbruck, Austria
Tel: +43-512-507 5451, Fax: +43-512-507 2924
E-mail: piers96@uibk.ac.at.
http://info.uibk.ac.at/c/c7/c707/piers96/

CHIRAL'96

Moscow - St. Petersburg, Russia, 23-30 July, 1996

The International Workshop on Electromagnetics of Chiral, Bi-isotropic, and Bi-anisotropic Media follows the line of the specialists meetings in Espoo, Finland (Bi-isotropics'93, February 1993), Gomel, Belarus (Bi-anisotropics'93, October 1993), Perigueux, France (Chiral'94, May 1994), and at Penn State University, USA (Chiral'95, October 1995).

The cross-disciplinary meeting is devoted to discussions of the latest developments in electromagnetics, materials sciences, and applications of novel composite materials for microwave and optical technology. The emphasis is on the bi-anisotropic materials whose most interesting feature is the magnetoelectric interaction of the fields. This domain promises applications in radar technology, aerospace, microwave engineering, manufacturing technology, etc. This year, the Workshop will be held parallel to the Fourth International Conference on Electric Transport and Optical Properties of Inhomogeneous Media (ETOPIM4). That conference will discuss electromagnetic wave propagation in composite materials, properties of porous media, thin films, percolation, etc.

Topics :

- Fundamental electromagnetic theory of bi-anisotropic media
- Electromagnetic waves and excitation in chiral and bi-anisotropic media
- Optics of anisotropic media

- Waveguides and other components with complex media inclusions
- Modelling of complex composite materials
- Scattering by particles of complex shapes
- Multiple scattering
- Knots and knotted media
- Methods of measurement
- Experimental set-ups
- Applications of novel complex composite materials

The programme will consist of invited and contributed presentations, as well as round-table discussions.

Abstract deadline : 1 February , 1996.

Please send one-page abstract of contributed papers to Dr. Ari Sihvola Electromagnetics Laboratory Helsinki University of Technology Otakaari 5 A FIN-02150 Espoo Finland Fax: +358-0-451-2267 E-mail: ari.sihvola@hut.fi

Your suggestion for round-table discussion topics are also welcome. The working language of the Workshop will be English, and all abstracts and papers must be in English.

The Workshop will be held as a river-boat trip from Moscow to St. Petersburg through the Moskva and Volga rivers, Volgo-Balt channel system, and the Ladoga lake. Participants will be picked up at the Moscow International Airport and supervised transportation in St. Petersburg will be provided. The river trip takes 6 days. In addition, the ship will stay for 3 days in Moscow and, after the trip, for 3 more days in St. Petersburg. Visits to scientific institutions of both cities will be organised. The programme will give a rare and excellent opportunity to discover and enjoy not only Moscow and St. Petersburg but also old Russian towns, famous monasteries, and Russian nature.

For further information, please contact

the Workshop Co-ordinator :

Dr. Alexei Vinogradov
Scientific Centre for Applied Problems
in Electrodynamics IVTAN
Izhorskaya 13/19 127412, Moscow, Russia
Fax: +7-095-484-2633 E-mail: vin@eldyn.msk.ru

26th European Microwave Conference

Prague, Czech Republic, 9-13 September 1996

The International Conference Designed for the Microwave Community will be held at Hotel Hilton Atrium, Prague, Czech Republic on 9-12 September 1996, the exhibition on 9-19 September and the workshops on 13 September 1996. In co-operation with: the Czech Technical University, Prague, Faculty of Electrical Engineering, Department of Electromagnetic Field; the Czech Electrotechnical Society, The Institution of Electrical Engineers, The Institute of Electrical and Electronics Engineers - Region 8, MTT Society and Czechoslovac Section and URSI.

In association with: Nexus Information Technology.

Topics

1. Terrestrial and satellite communications
2. Mobile and personal radiocommunications
3. Active and passive radars, remote sensing
4. Antennas and propagation
5. Millimetre and sub-millimetre waves, components, circuits
6. Microwave and lightwave interaction
7. Solid state devices, modelling and technology
8. Active circuits and systems
9. Passive components and circuits
10. Linear and non linear CAD
11. Microwave measurements and new materials
12. Field theory
13. Industrial, biological, environmental and scientific applications
14. Electromagnetic compatibility, packaging and interconnections

Contributions

Summaries of papers describing new work in the areas listed above are invited for consideration by the Technical Programme Committee and should be received by 2 February 1996. The summaries should be in English, and send to: Professor Jan Machac, 26th EuMC Conference Secretary Czech Technical University, Technicka 2, 16627 Prague 6 Czech Republic.

Technical Programme Committee

Chairman : J.Zehentner, Czech Technical University

Workshops

Three workshops will be organised on Friday 13 September 1996 at the Hotel Hilton Atrium, Prague, Czech Republic.

1. Open transmission lines for millimetric applications Organiser: T.Rozzi, University of Ancona, Italy
2. New microwave sensors and industrial applications Organiser: J.Detlefsen, TU Munich, Germany
3. Rapidly developing East/West economic relations bring forward new perspectives for micro/millimetrewave applications Organiser: H.Meinel, Daimler Benz, Germany

Prize

The Management Committee will award the EuMC Microwave Prize of SF 1000 to the author(s) of the best paper presented at the conference.

Exhibition

There will be an exhibition in conjunction with the conference from 9-12 September 1996 at the Hotel Hilton Atrium, Prague, Czech Republic

For more information, please contact :

Gillian Shinar, 26th EuMC Conference
Nexus Information Technology
Nexus House, Swanley, Kent BR8 8HY, UK
Tel.: +44 1322-660070
Fax: +44 1322-661257

January 1996

Pulsars

Sydney, Australia, 8-12 January 1996

Contact : Dr. Dick Manchester, Radiophysics, CSIRO, P.O. Box 76, Epping, NSW 2121, Australia, Fax : +61 2-372 4400, E-mail : rmanches@atnf.csiro.au

March 1996

EUSAR'96

Konigswinter, Germany, 26-28 March 1996

Contact : Dr. R. Klemm, FGAN-FFM, Neuenahrer Str. 20, D-53343 Wachtberg, Germany, Tel. : +49 228-852-377, Fax : +49 228-348 953, E-mail : r.klemm@elserv.ffm.fgan.de

May 1996

IGARSS'96

Burnham Yates Conference Center, Cornhusker Hotel, Lincoln, Nebraska, USA, 27-31 May 1996

Contact: Ms. Tammy Stein, IEEE Geoscience and Remote Sensing Society, 2610 Lakeway Drive, Seabrook, Texas 77586-1587, USA, Tel. : +1-713 291 9222, Fax : +1-713 291 9224, E-mail : stein@harc.edu

June 1996

10th Int. Conf. on Atmospheric Electricity

Osaka, Japan, 10-14 June 1996

Contact : Prof. M. Hayakawa, The University of Electro-Communications, 1-5-1 Chofugaoka, Chofu Tokyo 182, Japan, Fax : +81 424-80-3801, E-mail : hayakawa@ aurora.ee.uec.ac.jp

CPEM'96

Braunschweig, Germany, 17-20 June 1996

Contact: Mrs. Sabine Rost, Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany, Tel. : +49 531-592-2129, Fax : +49 531-592-2105, E-mail : erich.braun@ptb.de

13th International Wroclaw Symposium and Exhibition on Electromagnetic Compatibilty

Wroclaw, Poland, 25-28 June 1996

Contact : Mr. W. Moron, EMC Symposium 1996, Box 2141, 51-645 Wroclaw, Poland, Tel. : +48 71-728812, Fax : +48 71-728878

July 1996

Fifth International Symposium on Bio-Astronomy

Capri, Italy, 1-5 July 1996

Contact : Prof. Stuart Bowyer, Space Sciences Laboratory, University of California, Berkeley, CA 94720-7450, USA, Fax : +1-510 643-8303, E-mail : bowyer@ssl.berkeley.edu

COSPAR Scientific Assembly

Birmingham, United Kingdom, 14-21 July 1996

Contact : Prof. S. Grzedzielski, 51, bd de Montmorency, F-75016 Paris, France, Tel. : +33 1-4525 0679, Fax : +33 1-4050 9827, E-mail : cospar@paris7.jussieu.fr

CHIRAL'96

Moscow - St. Petersburg, Russia, 23-30 July 1996

Contact : Dr. Alexei Vinogradov Scientific Centre for Applied Problems in Electrodynamics IVTAN, Izhorskaya 13/19 127412, Moscow, Russia, Fax : +7-095 484-2633, E-mail : vin@eldyn.msk.ru

August 1996

XXVth URSI General Assembly

Lille, France, 28 August -5 September 1996

Contact : Dr. M. Lienard, Université de Lille, Dept. Electronique, Bat. P3, F-59655 Villeneuve d'Ascq Cedex, France, Tel : +33 20-337 134, Fax : +33 20-436 523, E-mail : agursi@univ-lille1.fr

September 1996

8° Colloque internationale et exposition sur la Compatibilité électromagnétique

Lille, France, 3-5 September 1996 (co-located with the URSI General Assembly)

Contact : Prof. P. Degauque, Université des Sciences et Techniques de Lille 1, UFR/IEEA, Bâtiment P3, F-59655 Villeneuve d'Ascq Cedex, France, Tel. : +33 20-434849, Fax : +33 20-436523

Sixth International Conference for Mathematical Methods in Electromagnetic Theory (MMET'96)

Lviv, Ukraine, 10-13 September 1996

Contact : Prof. Z. Nazarchuk, Karpenko Physico-Mechanical Institute, 5 Naukova St., Lviv 290601, Ukraine, Tel. : +380 322-637038, Fax : +380 322-649427

ECOC'96 - 22nd European Conference on Optical Communication

Oslo, Norway, 15-19 September 1996

Contact : ECOC'96 Secretariat, Norwegian Telecom Research, P.O. Box 83, N-2007 Kjeller, Norway
Tel. : +47 63-80 9341, Fax : +47 63-81 9810, E-mail : krosby@tf.tele.no

IEEE ISSSTA'96

Mainz, Germany, 22-25 September 1996

Contact : Prof. P.W. Baier, Research Group for RF Communications, University of Kaiserslautern, P.O. Box 3049, D-67653 Kaiserslautern, Germany, Tel. and Fax : +49 631-205-2075/3612, E-mail : baier@rhrk.uni-kl.de

23rd International Conference on Lightning Protection (ICLP)

Firenze, Italy, 23-27 September 1996

Contact : Prof. C Mazzetti, Dept. of Electrical Engineering, University of Rome "La Sapienza", Via Eudossiana 18, I-00184 Rome, Italy, Tel. : +39 6-4458 5534, Fax : +39 6-488 3235, E-mail : elettrica@risccics.ing. uniromal.it

Int. Symp. on Antennas and Propagation

Chiba, Japan, 24-27 September 1996

Contact : Prof. Kiyohiko Itoh, Faculty of Engineering, Hokkaido University, Sapporo 060, Japan, Fax : +81 11-706-7836, E-mail : itoh@densi001.hudk.hokudai.ac.jp

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

International Geophysical Calendar 1996

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

S	M	T	W	T	F	S	
	1	2	3	4	5	6	JULY
7	8	9	10	11	12	13	
14	15	16*+	17*+	18	19	20	
21	22	23	24	25	26	27	
28	29	30	31	1	2	3	AUGUST
4	5	6	7	8	9	10	
11	12	13*+	14*+	15	16	17	
18	19	20	21	22	23	24	
25	26	27	28	29	30	31	
1	2	3	4	5	6	7	SEPTEMBER
8	9	10	11*	12*	13	14	
15	16	17+	18+	19	20	21	
22	23	24	25	26	27	28	
29	30	1	2	3	4	5	OCTOBER
6	7	8+	9+	10+	11+	12+	
13	14	15*	16*	17	18	19	
20	21	22	23	24	25	26	
27	28	29	30	31	1	2	NOVEMBER
3	4	5	6	7	8	9	
10	11+	12*+	13*+	14+	15	16	
17	18	19	20	21	22	23	
24	25	26	27	28	29	30	
1	2	3	4	5	6	7	DECEMBER
8	9	10*+	11*+	12	13	14	
15	16	17	18	19	20	21	
22	23	24	25	26	27	28	
29	30	31	1	2	3	4	1997
5	6+	7+	8+	9+	10+	11	JANUARY
12	13	14*	15*	16	17	18	
19	20	21	22	23	24	25	
26	27	28	29	30	31		
S	M	T	W	T	F	S	

16 Regular World Day (RWD)

17 Priority Regular World Day (PRWD)

20 Quarterly World Day (QWD) also a PRWD and RWD

3 Regular Geophysical Day (RGD)

11 12 World Geophysical Interval (WGI)

22+ Incoherent Scatter Coordinated Observation Day

12 Day of Solar Eclipse

17 18 Airglow and Aurora Period

17* 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 Ursigram and World Days Service (IUWDS) with the advice of spokesmen for the various scientific disciplines. For some programs, greater detail concerning recommendations appears from time to time published in IAGA News, IUGG Chronicle, URSI Information Bulletin or other scientific journals or newsletters. For on-line information, see http://www.sel.noaa.gov/iuwds/iuwds.html.

The definitions of the designated days remain as described on previous Calendars. Universal Time (UT) is the standard time for all world days. Regular Geophysical Days (RGD) are each Wednesday. Regular World Days (RWD) are three consecutive days each month (always Tuesday, Wednesday and Thursday near the middle of the month). Priority Regular World Days (PRWD) are the RWD which fall on Wednesdays. Quarterly World Days (QWD) are one day each quarter and are the PRWD which fall in the World Geophysical Intervals (WGI). The WGI are fourteen consecutive days in each season, beginning on Monday of the selected month, and normally shift from year to year. In 1996 the WGI will be March, June, September and December.

The Solar Eclipses are: a.) 17-18 April 1996 (partial) is visible from New Zealand, except for the northern part of its northern island. Its other landfalls are parts of Antarctica—Victoria Land and Marie Byrd Land. The partial eclipse is also visible from much of the South Pacific Ocean east of New Zealand, with a maximum of 88% of the sun's diameter covered. Greatest eclipse occurs at 2237 UT. Tahiti is near the edge of this zone, with the sun barely eclipsed— 3.9% (16% at Christchurch, NZ). b.) 12 October 1996 (partial) will be visible from extreme northern Maine, northeast Canada (almost all of New Brunswick, northeastern Nova Scotia, Newfoundland, Labrador, northern Quebec, northern Ontario, and eastern Northwest Territories), Greenland, Iceland, Europe (including the British Isles), and North Africa. Maximum eclipse occurs at 1402 UT. At most, 76% of the sun's diameter will be covered (4% at Charlottetown, PEI, Canada, 16% at St. John's, NF, Canada, 63% in Amsterdam, 72% in Helsinki, 61% in London, and 59% in Paris). (Descriptions by Dr. Jay M. Pasachoff, Williams College (jmp@williams.edu)—Hopkins Observatory, Chair of the Working Group on Eclipses of the International Astronomical Union, based on "Fifty-Year Canon of Solar Eclipses: 1986-2035," by Fred Espenak, NASA Goddard Space Flight Center, NASA Reference Publication 1178 Revised.)

Meteor Showers (selected by R. Hawkes, Mount Allison Univ, Canada, rhawkes@mta.ca) include the most prominent regular showers. The dates for Northern Hemisphere meteor showers are: Jan 3-5 (Quadrantid); Apr 21-23 (Lyrid); May 3-6 (Eta-Aquarid); Jun 6-11 (Arietid, Zeta-Perseid); Jun 27-29 (Beta-Taurid); Aug 11-14 (Perseid); Oct 21-23 (Orionid); Nov 16-19 (Leonid); Dec 13-15 (Geminid); Dec 22-23, 1996 (Ursid); and Jan 3-5, 1997 (Quadrantid). The dates for Southern Hemisphere meteor showers are: May 3-6 (Eta-Aquarid); Jun 6-11 (Arietid, Zeta-Perseid); Jun 27-29 (Beta-Taurid); Jul 28-31 (S. Delta-Aquarid, Alpha-Aurigid); Oct 21-23 (Orionid); Nov 16-19 (Leonid); and Dec 13-15, 1996 (Geminid). Particular attention is drawn to observations of the Leonid shower as part of the International Leonid Watch which will continue throughout the decade.

The occurrence of unusual solar or geophysical conditions is announced or forecast by the IUWDS through various types of geophysical "Alerts" (which are widely distributed by telegram and radio broadcast on a current schedule). Stratospheric warmings (STRATWARM) are also designated. The meteorological telecommunications network coordinated by WMO carries these worldwide Alerts once daily soon after 0400 UT. For definitions of Alerts see IUWDS "Synoptic Codes for Solar and Geophysical Data", March 1990 and its amendments. Retrospective World Intervals are selected and announced by MONSEE and elsewhere to provide additional analyzed data for particular events studied in the ICSU Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) programs.

RECOMMENDED SCIENTIFIC PROGRAMS
OPERATIONAL EDITION

(The following material was reviewed in 1995 by spokesmen of IAGA, WMO and URSI as suitable for coordinated geophysical programs in 1996.)

Airglow and Aurora Phenomena. Airglow and auroral observatories operate with their full capacity around the New Moon periods. However, for progress in understanding the mechanism of many phenomena, such as low latitude aurora, the coordinated use of all available techniques, optical and radio, from the ground and in space is required. Thus, for the airglow and aurora 7-day periods on the Calendar, ionosonde, incoherent scatter, special satellite or balloon observations, etc., are especially encouraged. Periods of approximately one weeks' duration centered on the New Moon are proposed for high resolution of ionospheric, auroral and magnetospheric observations at high latitudes during northern winter.

Atmospheric Electricity. Non-continuous measurements and data reduction for continuous measurements of atmospheric electric current density, field, conductivities, space charges, ion number densities, ionosphere potentials, condensation nuclei, etc.; both at ground as well as with radiosondes, aircraft, rockets; should be done with first priority on the RGD each Wednesday, beginning on 3 January 1996 at 0000 UT, 10 January at 0600 UT, 17 January at 1200 UT, 24 January at 1800 UT, etc. (beginning hour shifts six hours each week, but is always on Wednesday). Minimum program is at the same time on PRWD beginning with 17 January at 1200 UT. Data reduction for continuous measurements should be extended, if possible, to cover at least the full RGD including, in addition, at least 6 hours prior to indicated beginning time. Measurements prohibited by bad weather should be done 24 hours later. Results on sferics and ELF are wanted with first priority for the same hours, short-period measurements centered around the minutes 35-50 of the hours in- dicated. Priority Weeks are the weeks which contain a PRWD; minimum priority weeks are the ones with a QWD. The World Data Centre for Atmospheric Electricity, 7 Karbysheva, St. Petersburg 194018, USSR, is the collection point for data and information on measurements.

Geomagnetic Phenomena. It has always been a leading principle for geomagnetic observatories that operations should be as continuous as possible and the great majority of stations undertake the same program without regard to the Calendar.

Stations equipped for making magnetic observations, but which cannot carry out such observations and reductions on a continuous schedule are encouraged to carry out such work at least on RWD (and during times of MAGSTORM Alert).

Ionospheric Phenomena. Special attention is continuing on particular events which cannot be forecast in advance with reasonable certainty. These will be identified by Retrospective World Intervals. The importance of obtaining full observational coverage is therefore stressed even if it is possible to analyze the detailed data only for the chosen events. In the case of vertical incidence sounding, the need to obtain quarter-hourly ionograms at as many stations as possible is particularly stressed and takes priority over recommendation (a) below when both are not practical.

For the vertical incidence (VI) sounding program, the summary recommendations are: (a) All stations should make soundings on the hour and every quarter hour; (b) On RWDs, ionogram soundings should be made at least every quarter hour and preferably every five minutes or more frequently, particularly at high latitudes; (c) All stations are encouraged to make f-plots on RWDs; f-plots should be made for high latitude stations, and for so-called "representative" stations at lower latitudes for all days (i.e., including RWDs and WGIs) (Continuous records of ionospheric parameters are acceptable in place of f-plots at temperate and low latitude stations); (d) Copies of hourly ionograms with appropriate scales for QWDs are to be sent to WDCs; (e) Stations in the eclipse zone and its conjugate area should take continuous observations on solar eclipse days and special observations on adjacent days. See also recommendations under Airglow and Aurora Phenomena.

For the incoherent scatter observation program, every effort should be made to obtain measurements at least on the Incoherent Scatter Coordinated Observation Days, and intensive series should be attempted whenever possible in WGIs, on Dark Moon Geophysical Days (DMGD) or the Airglow and Aurora Periods. The need for collateral VI observations with not more than quarter-hourly spacing at least during all observation periods is stressed. Special programs include: CADITS/MLTCS/ABC — Coupling and Dynamics of the Ionosphere-Thermosphere System/ Mesosphere, Lower-Thermosphere Coupling Study — combined local E and F region measurements, including vector velocities, with 15 minute time resolution. Latitudinal coverage may be sacrificed to meet this goal. The goal of ABC is to look for predictors to equatorial spread-F effects that can be sensed PRIOR to actual onset times, i.e., from the pre-sunset to pre-midnight period; DATABASE — Incoherent Scatter Database — emphasis on broad latitudinal coverage of the F region; FAST — Fast Auroral Snapshot — coordinated FAST satellite observations with GISMOS; GISMOS — Global Ionospheric Simultaneous Measurements of Substorms — wide latitudinal coverage of convection with highest possible time resolution; JOULE — coordinated radar/ground-based optics/satellite (MSX) campaign to measure Joule heating and its effects on the atmosphere; MISETA — Equatorial Dynamics — The MISETA-2 campaign has as its goal the study of the onset and evolution of equatorial spread-F effects under Vernal Equinox conditions. Local E and F region measurements will be included; POLITE — Plasmaspheric Observations of Light Ions in the Topside Exosphere — global coordinated measurements of topside light ions. Simultaneous optical observations of neutral hydrogen and helium are highly desirable where possible.; SUNDIAL — Weather and climatology of the global ionospheric-thermospheric system. Full 30 day round-the-clock ionosonde coverage of E- and F-region characteristics including intermediate, descending and sequential layers. Special programs: Dr. J. Holt, M.I.T. Haystack Observatory, Route 40, Westford, MA 01886 U.S.A., URSI Working Group G.5. Phone (617)981-5625, jmh@chaos.haystack.edu.

For the ionospheric drift or wind measurement by the various radio techniques, observations are recommended to be concentrated on the weeks including RWDs.

For traveling ionosphere disturbances, propose special periods for coordinated measurements of gravity waves induced by magnetospheric activity, probably on selected PRWD and RWD.

For the ionospheric absorption program half-hourly observations are made at least on all RWDs and half-hourly tabulations sent to WDCs. Observations should be continuous on solar eclipse days for stations in eclipse zone and in its conjugate area. Special efforts should be made to obtain daily absorption measurements at temperate latitude stations during the period of Absorption Winter Anomaly, particularly on days of abnormally high or abnormally low absorption (approximately October-March, Northern Hemisphere; April-September, Southern Hemisphere).

For back-scatter and forward scatter programs, observations should be made and analyzed on all RWDs at least.

For synoptic observations of mesospheric (D region) electron densities, several groups have agreed on using the RGD for the hours around noon.

For ELF noise measurements involving the earth-ionosphere cavity resonances any special effort should be concentrated during the WGIs.

It is recommended that more intensive observations in all programs be considered on days of unusual meteor activity.

Meteorology. Particular efforts should be made to carry out an intensified program on the RGD — each Wednesday, UT. A desirable goal would be the scheduling of meteorological rocketsondes, ozone sondes and radiometer sondes on these days, together with maximum-altitude rawinsonde ascents at both 0000 and 1200 UT.

During WGI and STRATWARM Alert Intervals, intensified programs are also desirable, preferably by the implementation of RGD-type programs (see above) on Mondays and Fridays, as well as on Wednesdays.

Global Atmosphere Watch (GAW) The World Meteorological Organizations (WMO) GAW integrates many monitoring and research activities involving measurement of atmospheric composition. Serves as an early warning system to detect further changes in atmospheric concentrations of greenhouse gases, changes in the ozone layer and in the long range transport of pollutants, including acidity and toxicity of rain as well as of atmospheric burden of aerosols (dirt and dust particles). Contact WMO, 41, avenue Giuseppe-Motta, P.O. Box 2300, 1211 Geneva 2, Switzerland.

Solar Phenomena. Observatories making specialized studies of solar phenomena, particularly using new or complex techniques, such that continuous observation or reporting is impractical, are requested to make special efforts to provide to WDCs data for solar eclipse days, RWDs and during PROTON/FLARE ALERTS. The attention of those recording solar noise spectra, solar magnetic fields and doing specialized optical studies is particularly drawn to this recommendation.

FLARES22(FLAre RESearch at the maximum of solar cycle 22). 1990-1997 worldwide Solar-Terrestrial Energy Program (STEP) project. Aimed at understanding basic physical processes of transient solar activity and its coupling with the solar-terrestrial environment, including times of the various solar ALERTS. Coordinates satellite and ground-based observations. Observational campaigns are driven by specific scientific objectives rather than observations per se. Satellites include SOLAR-A, GRO, CORONAS, WIND, GEOTAIL, ULYSSES, etc. Program will focus on international collaboration of data analyses and theoretical work via electronic mail and workshops. For more information, contact Dr. Mona J. Hagyard, Marshall Space Flight Center, Code ES52, Huntsville, AL 35812. 205-544-7612; e-mail mhagyard@solar.stanford.edu.

SOLTIP (SOlar connection with Transient Interplanetary Processes). Program within the SCOSTEP STEP (Solar-Terrestrial Energy Program) project: 1990-1997. Its focus is on remote and in situ observations and analyses of solar-generated phenomena and their propagation throughout the heliosphere, including times following the various solar ALERTS. Desired goals include: (1) interplanetary scintillation observation of remote radio galaxies as well as telemetry signals to/from interplanetary spacecraft; (2) coordination of Earth-orbiting spacecraft such as IMP-8 in the solar wind and solar-orbiting spacecraft such as ICE, GIOTTO, SAKIGAKE, VOYAGER 1/2, PIONEER 10/11, ULYSSES, RELICT, WIND, SOHO, Galileo, and ACE. Contact is Dr. M. Dryer, NOAA R/E/SE, 325 Broadway, Boulder, CO 80303 USA. Phone: (303)497-3978; FAX number (303)497-3645; e-mail address mdryer@sel.noaa.gov.

Space Research, Interplanetary Phenomena, Cosmic Rays, Aeronomy. Experimenters should take into account that observational effort in other disciplines tends to be intensified on the days marked on the Calendar, and schedule balloon and rocket experiments accordingly if there are no other geophysical reasons for choice. In particular it is desirable to make rocket measurements of ionospheric characteristics on the same day at as many locations as possible; where feasible, experimenters should endeavor to launch rockets to monitor at least normal conditions on the Quarterly World Days (QWD) or on RWDs, since these are also days when there will be maximum support from ground observations. Also, special efforts should be made to assure recording of telemetry on QWD and Airglow and Aurora Periods of experiments on satellites and of experiments on spacecraft in orbit around the Sun.

The International Ursigram and World Days Service (IUWDS) 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. IUWDS adheres to the Federation of Astronomical and Geophysical Data Analysis Services (FAGS) of the International Council of Scientific Unions (ICSU). The IUWDS coordinates the international aspects of the world days program and rapid data interchange.

This Calendar for 1996 has been drawn up by H.E. Coffey, of the IUWDS Steering Committee, in association with spokesmen for the various scientific disciplines in SCOSTEP, IAGA and URSI and other ICSU organizations. Similar Calendars are issued annually beginning with the IGY, 1957-58, and are published in various widely available scientific publications.

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Additional copies are available upon request to IUWDS Chairman, Dr. R. Thompson, IPS Radio and Space Services, Department of Administrative Services, P.O. Box 5606, West Chatswood, NSW 2057, Australia (FAX number (61)(2)414 8331; e-mail richard@ips.gov.au), or IUWDS Secretary for World Days, Miss H.E. Coffey, WDC-A for Solar-Terrestrial Physics, NOAA E/GC2, 325 Broadway, Boulder, Colorado 80303, USA (FAX number (303)497-6513; e-mail hcoffey@ngdc.noaa.gov).

This calendar is available on-line at http://www.sel.noaa.gov/iuwds/iuwds.html.

NOTES on other dates and programs of interest:

1. Days with significant meteor shower activity are: Northern Hemisphere 3-5 Jan; 21-23 Apr; 3-6 May; 6-11, 27-29 Jun; 11-14 Aug; 21-23 Oct; 16-19 Nov; 13-15, 22-23 Dec 1996; 3-5 Jan 1997. Southern Hemisphere 3-6 May; 6-11, 27-29 Jun; 28-31 Jul; 21-23 Oct; 16-19 Nov; 13-15 Dec 1996.
2. GAW (Global Atmosphere Watch) — early warning system for changes in greenhouse gases, ozone layer, and long range transport of pollutants. (See Explanations.)
3. SOLTIP (Solar connection with Transient Interplanetary Processes). Observing Program 1990 - 1997: solar-generated phenomena and their propagation throughout the heliosphere. (See Explanations.)
4. FLARES22 (FLAre RESearch at solar cycle 22 maximum). Observing Program 1990-1997: basic physical processes of transient solar activity and its coupling with solar-terrestrial environment. (See Explanations.)
5. Day intervals that IMP 8 satellite is in the solar wind (begin and end days are generally partial days): 6-13 Jan; 18-25 Jan; 31 Jan-7 Feb; 12-20 Feb; 24 Feb-3 Mar; 7-16 Mar; 20-28 Mar; 1-10 Apr; 14-23 Apr; 27 Apr-5 May; 10-18 May; 22-30 May; 3-11 Jun; 16-24 Jun; 28 Jun-6 Jul; 11-18 Jul; 24-31 Jul; 5-13 Aug; 18-25 Aug; 30 Aug-7 Sep; 12-19 Sep; 25 Sep-2 Oct; 8-15 Oct; 21-27 Oct; 2-9 Nov; 15-22 Nov; 28 Nov-4 Dec; 10-17 Dec; 23-29 Dec 1996. Note that there will not necessarily be total IMP 8 data monitoring coverage during these intervals. Also please note that WIND data should be available. (Information kindly provided by the WDC-A for Rockets and Satellites, NASA GSFC, Greenbelt, MD 20771 U.S.A.).
6. + Incoherent Scatter Coordinated Observations Days (see Explanations) starting at 1600 UT on the first day of the intervals indicated, and ending at 1600 UT on the last day of the intervals: 22-24 Jan 1996 GISMOS/FAST; 13-14 Feb POLITE; 19-22 Mar MISETA/CADITS/MLTCS; 16-17 Apr DATABASE; 14-15 May DATABASE; 18-19 Jun SUNDIAL; 16-17 Jul DATABASE; 13-14 Aug DATABASE; 17-18 Sep DATABASE; 8-12 Oct CADITS/MLTCS/ABC; 11-14 Nov POLITE; 10-11 Dec DATABASE; 6-10 Jan 1997 CADITS/MLTCS

where ABC = APL-BU-Cornell — Predictors to equatorial spread-F (ESF) effects; CADITS = Coupling and Dynamics of the Ionosphere-Thermosphere System; DATABASE = Incoherent Scatter Database; FAST = Fast Auroral Snapshot (with FAST satellite); GISMOS = Global Ionospheric Simultaneous Measurements of Substorms; MISETA = Equatorial Dynamics — Onset/evolution of ESF during vernal equinox; MLTCS = Mesosphere, Lower-Thermosphere Coupling Study; POLITE = Plasmapheric Observations of Light Ions in the Topside Exosphere; SUNDIAL = Coordinated study of the ionosphere/magnetosphere.

OPERATIONAL EDITION, September 1995

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JOURNAL OF ATMOSPHERIC AND TERRESTRIAL PHYSICS

The *Journal of Atmospheric and Terrestrial Physics* is an international journal concerned with the interdisciplinary science of the Earth's atmospheric and space environment. Papers are published on the results of experiments and their interpretations, and on theoretical or modelling studies. Papers dealing with remote sensing carried out from the ground or with *in situ* studies made from rockets or from satellites orbiting the Earth are particularly suitable. Plans for future research, often carried out as an international programme, are also discussed. Besides original research papers, discussion papers and short reports, the journal includes commissioned review papers on topical subjects and special issues arising from chosen scientific symposia or workshops.

The journal covers the physical processes operating in the troposphere, stratosphere, mesosphere, thermosphere, ionosphere, magnetosphere and heliosphere. Phenomena occurring in other 'spheres' and supporting laboratory measurements are also considered. The journal deals especially with the coupling between the different regions. Regarding the upper atmosphere, the subjects of aeronomy, geomagnetism, auroral phenomena, radio wave propagation and plasma instabilities are examples within the broad field of solar-terrestrial physics which emphasise the energy exchange between the solar wind, the magnetospheric and ionospheric plasmas, and the neutral gas. In the middle and lower atmosphere, the topics covered include dynamics, radiation and chemistry, atmospheric electricity and electrodynamic effects, including lightning and its effects, and anthropogenic changes. Helpful, novel schematic diagrams are encouraged as is the use of colour.

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A Selection of Papers

Yu.I. PORTNYAGIN (Russia), **J.M. FORBES** (USA), **G.J. FRASER** (New Zealand), **R.A. VINCENT** (Australia), **S.K. AVERY** (USA), **I.A. LYSENKO, N.A. MAKAROV** (Russia), Dynamics of the Antarctic and Arctic mesosphere and lower thermosphere regions-II. The semidiurnal tide.

K. IGARASHI, S. KAINUMA, I. NISHIMUTA, S. OKAMOTO, H. KUROIWA, T. TANAKA, T. OGAWA (Japan), Ionospheric and atmospheric disturbances around Japan caused by the eruption of Mount Pinatubo on 15 June 1991.

M.L. CHANIN, A. HAUCHECORNE, A. GARNIER, D. NEDELJKOVIC (France), Recent lidar developments to monitor stratosphere - troposphere exchange.

J.K. CHAO, H.H. CHEN, A.J. CHEN (Taiwan), **L.C. LEE** (USA), A 22-yr variation of geomagnetic activity and interplanetary magnetic field.

S. ISRAELSSON (Sweden), The effects of wind and evaporation on space charge formation at the ground.

H. KOHL, H. KOPKA, P. STUBBE (Germany), **M.T. RIETVELD** (Norway), Introduction to ionospheric heating experiments at Tromso-II. Scientific problems.

J. BOSKOVA, F. JIRICEK, J. SMILAUER, P. TRISKA (Czechoslovakia), **V.V. AFONIN, V.G. ISTOMIN** (Russia), Plasmaspheric refilling phenomena observed by the Intercosmos 24 satellite.

T.R. ROBINSON, F. HONARY (UK), Adiabatic and isothermal ion-acoustic speeds of stabilized Farley-Buneman waves in the auroral E-region.

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News from ICSU

Our President, Dr. P. Bauer, asked us to publish the following excerpt from the report of the 34th meeting of the General Committee of ICSU - the International Council of Scientific Unions - which was held in Chiang Mai, Thailand, from 7 to 9 October, 1995.

Recommendation 4 :
The General Committee notes with interest the review reports on CODATA (Committee on Data for Science and Technology), WDC (World Data Centre) and FAGS (Federation of Astronomical and Geophysical Services) and the comments on those reports received from each body reviewed and believes that each of these bodies serves an important and sufficiently distinct purpose to justify its separate and continued existence.
It is clear that the World Data Centres deal with data concerning the earth's environment, while the Committee on Data for Science and Technology concerns itself with data concerning other fields of science. The General Committee particularly recommends that CODATA and WDC pay attention to the evolving needs of users and to include, as far as possible, information on the quality of their data. It notes that while cooperation between FAGS and WDC occurs naturally, all three bodies should also compare their methodologies in order to benefit from their individual experiences.

News from the URSI Community

NEWS FROM THE MEMBER COMMITTEES

INDIA

The General Assembly of the Indian URSI Committee will be held at the Science City and Institute of Radiophysics and Electronics in Calcutta, from 16 to 18 January and at the University of Burdwan on 19 and 20 January. The general theme is"Frontiers of radio science".

Topics

General radio science, solid state devices, millimetre-wave techniques, antennas including quasi-optics and optical control, microwave terrestrial, satellite and mobile communications, EMI/EMC, radio astronomy, remote sensing, wave propagation, radio science in developing countries, electromagnetic in biology and medicine.

Official language

English will be used for all printed materials, presentation, discussion and correspondence.

Dr. A.P. Mitra chairs the Scientific Advisory Committee.
Prof. G. Swarup chairs the National Organizing Committee.

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Note : An alphabetical index of names, with addresses and page references, is given on pages 52-63.

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the Chairman, A.D. Spaulding, passed away earlier this year;

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E.7. Extra-Terrestrial and Terrestrial Meteorologic-Electric Environment
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Secretary : R. Conkright (U.S.A.);

G.2. Studies of the Ionosphere Using Beacon Satellites
Chair : R. Leitinger (Austria)
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G.3 Incoherent Scatter
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G.4 Ionospheric Informatics
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J.2. Large Millimetre/Submillimetre Array
Coordinators : M. Ishiguro (Japan), R.S. Booth (Sweden)

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

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FG.1. Middle Atmosphere
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Co-Chair for Comm. G : Prof. S. Fukao (Japan)

GH.1. Active Experiments in Plasmas
Co-Chair for Commission G : Dr. Sa. Basu (U.S.A.)
Co-Chair for Commission H : Dr. P. Bernhardt (U.S.A.)

GH.2. Computer Experiments, Simulation and Analysis of Wave Plasma Processes
Co-Chair for Commission G : Dr. H. Thiemann (Germany)
Co-Chair for Commission H : Prof. H. Matsumoto (Japan)

Time Domain Waveform Measurements
Chair : Prof. T.K. Sarkar (U.S.A.)

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URSI/IAGA.1- VLF/ELF Remote Sensing of the Ionospheric and Magnetosphere (VERSIM)
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Co-Chair for Commission H : Dr. U.S. Inan (U.S.A.)

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IUCAF (Inter-Union Commission on Frequency Allocations for Radio Astronomy and Space Science) :
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