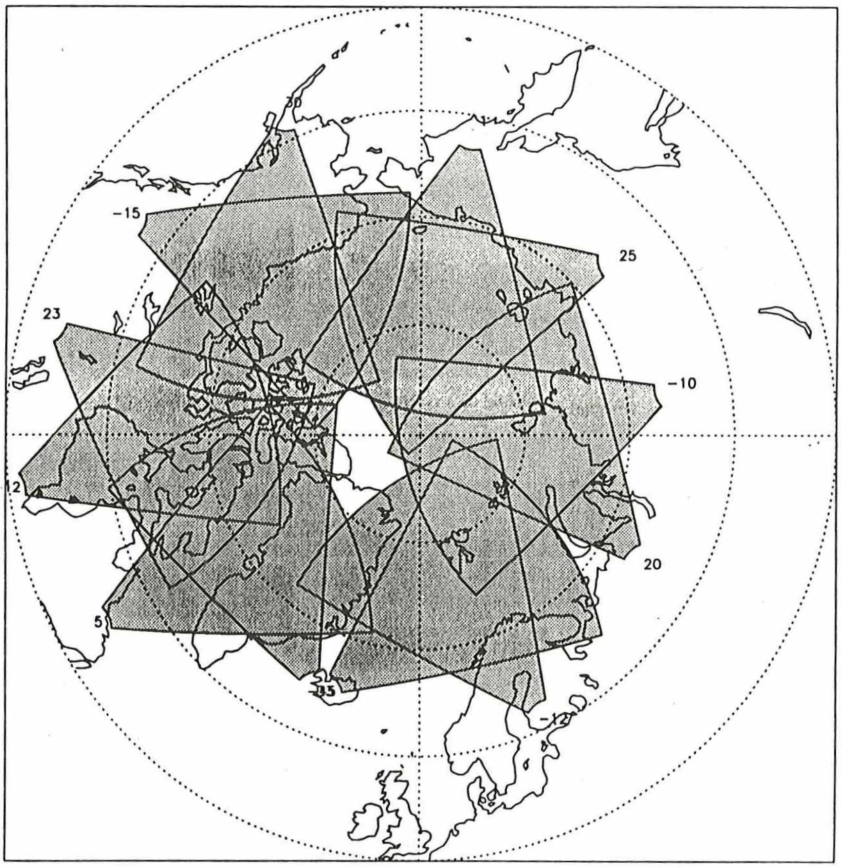
The Radioscientist

Special issue for the

URSI XXIVth General Assembly

Kyoto, Japan, August-September, 1993



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U.R.S.I. The Radioscientist

The Radioscientist is published quarterly by
Radio Science Press Avenue Circulaire 3
Brussels, B-1180, Belgium
and issued on **1st March, June, September and December.**

NOTICE TO CONTRIBUTORS

All material should be submitted direct to the Editor-in-Chief unless invited by one of the Associate Editors. Material for publication ("copy") is acceptable on paper, but is preferable in machine readable form to minimise the work by us volunteers. Please note that we cannot use Camera Ready Copy as such, though we can read it electronically (by OCR machine).
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Copy is best sent on 1.44 Mbyte, 3.5 inch disk in either IBM or Mac format. Formatted text from most word processors can be read into Macintosh Word 5 (which we use), but include a "flat" ASCII file as well. We can use (and edit if necessary) equations set in MathType in Mac *Word 5* or PC *Word for Windows.*
Photographs can be monochrome or colour but must be A4 or smaller to fit our flatbed scanner and be suitable for publication in greyscale. TIFF on disk (or compressed onto several disks with decompressor) are most welcome, but be sure to include photograph as well (which we will eventually return). Computer generated line drawings (graphs, etc.) submitted only on paper do not scan well (we do NOT use photography) and should be supplied as well as EPSF or plain PostScript.
The Editor reserves the right to accept, reject, defer and/or edit any material and all material submitted. Accepted papers are not necessarily published in the immediately following issue.

COVER: Hypothetical Northern Hemisphere SuperDARN network with four radars located in Russia.
The banner (The *Radioscientist*) has been rotated for this special Kyoto issue only. It has also been suggested for the new combined magazine.

URSI and the New World Order

We seem to be at a watershed in human history with a crumbling, or collapse, of old orders and an emergence of new. There are profound changes not only in political and economic structures but also in the structure of the science and technology which helped precipitate the changes. Certainly the physical sciences, and particularly radio science, flourished under government support during the decades of cold war competition. Just as surely radio science has vastly improved telecommunications and the rapid spread of information resulting in a weakening of government information control and a raising of public expectations. This process continues globally, creating difficulties for governments almost everywhere. While the early radio scientists who sowed these seeds of change may not be experiencing the fruits of their endeavour now, their successors surely are.

Our enormous relief at the dismantling of the deadly confrontation of the cold war era is accompanied by disruption and uncertainty in the careers of many of our colleagues. These are mainly in the research institutes of East Europe and the former Soviet Union and some research and development companies in the western nations. Here is a massive array of intellectual skills for scientific and economic benefit which should not be allowed to languish, but harnessing them will require time and especially economic growth and international cooperation. URSI has a vital role here for it was founded to further international cooperation in the radio sciences.

Indeed URSI was one of the first international scientific unions (1919) because the need for international cooperation existed from the beginnings of radio science. It has had a long and famous history, from early achievements in radio broadcasting to the spectacular discovery and exploitation of the ionosphere beginning in the 1920s. It survived very well the economic and political calamities of the 1930s and 1940s and emerged from the dark interlude of the war, during which it was unable to function, more active and broader in scope than before. It went on to help usher in a brilliant period of space research, first proposing instrumented satellites in 1954 and the International Geophysical Year (1957/58) which now has a successor in the IGBP. Its frequency range expanded to from ELF to optics and its spatial domain from the depths of the earth to the most distant reaches of the universe. Recently it has been extended to biological matter also. Who could have foreseen today's URSI 50 years ago and who would dare to predict the future URSI today?

This much is clear. The possibilities for and potential benefits of international cooperation in radio science probably have never been greater. Emerging from the collapse of the old order there appears to be an economically competitive but more globally cooperative society, which more than ever will require the radio sciences to function. Quite apart from other motivating factors, the competitive enthusiasm of the newly industrialised countries of Asia for new uses of radio sciences should encourage the pursuit of new discoveries. So also should the example of the remarkable scientific and industrial successes in telecommunications of Japan, our host country for this 24th General Assembly. Centres of activity in the radio sciences may shift geographically but the scale of activity is almost certain to increase. Progress in radio science will continue most efficiently if the traditions of URSI, that is international cooperation and the free circulation of scientists, are maintained. We must ensure that they are.

E V Jull

Editor's Column

The Editor's Page, which was usually a page and a half, is now a Column. This column — which may spread onto columns further on in later issues — will be about the logistics and mechanics of the issue, leaving the comment function to invited guest editors as here.

This issue is being put together about a month early to get it into the satchels of all scientific participants of this 24th General Assembly of URSI at Kyoto. For many of you, this is the first issue you have seen, and since you are also reading this column, let me give you a warm welcome to the readership and to the contributorship of *the Radioscientist* and *the Bulletin*. In case you have not realised it yet, this is a foretaste of the 3-year free subscription of the combined magazine which starts with the first issue of 1994. I hope you will see it as your magazine for you to communicate to the international community of radioscientists: comments (via Letters to the editor) and scientific and historical articles.

This 3-year free subscription is not all. You are also entitled to special discounted subscription rates for both *RADIO SCIENCE* and the *Journal of Atmospheric and Terrestrial Physics* (JATP), both of which now have URSI sponsorship and carry the URSI logo. The JATP subscription rates for URSI "members" (for the time being, all radioscientists who will receive the new URSI magazine) is a mere 10% of the library rate, but such a subscription must be only for one's personal use. Library cancellations of either journal traced to abuse of these discount privileges would jeopardise these arrangements. Be fair! For further details, see the advertisements for these journals later in this issue.

Sorry, this issue is thinner than usual (24 pages instead of 28). My backlog of articles is used up. Maybe this is because this issue is rather soon after the June issue. Why don't **you** write something for the December issue?

VLF HOLOGRAPHY

Introduction

It has long been known [1] that whistler amplification in the magnetosphere produces precipitation into the ionospheric D-region of energetic (> 40 keV) electrons from the Radiation Belts. Since whistlers are dispersed lightning impulses, this is called lightning-induced electron precipitation (LEP). Each energetic electron can produce thousands of electron-ion pairs, and so the LEP produces a lightning-induced ionisation enhancement (LIE). The lateral dimensions of a LIE may represent the D-region footprint or down-mapping of the guiding whistler duct, and are usually assumed to be of the order of 100 km.

In the Earth-ionosphere waveguide, the LIE appears to a horizontally travelling VLF wave as an anomaly within which the complex propagation vector **k** is perturbed by Δ**k**. As a result, the VLF wave is diffracted horizontally (this two-dimensional model is adequate for our purposes) in a pattern determined by the lateral dimensions and ionisation distribution of the LIE. At large distances "down wave" of the LIE (i.e. in the far field of the re-radiating LIE) the diffraction pattern is essentially the Fourier transform of the LIE and so the lateral dimensions of the LIE and the width of the far field diffraction pattern are inversely related.

LEP occurs ~1s after the lightning which induced it, corresponding to the whistler and electron travel times. The LEP duration ranges from a few tenths to a few seconds (e.g. due to whistler triggered emissions, multi hop whistlers, backscattered electrons, etc.). The LIE intensity variation in time is largely the integral of the LEP intensity, reaching maximum at about the end of LEP and then decaying exponentially with a time constant of about 30 seconds.

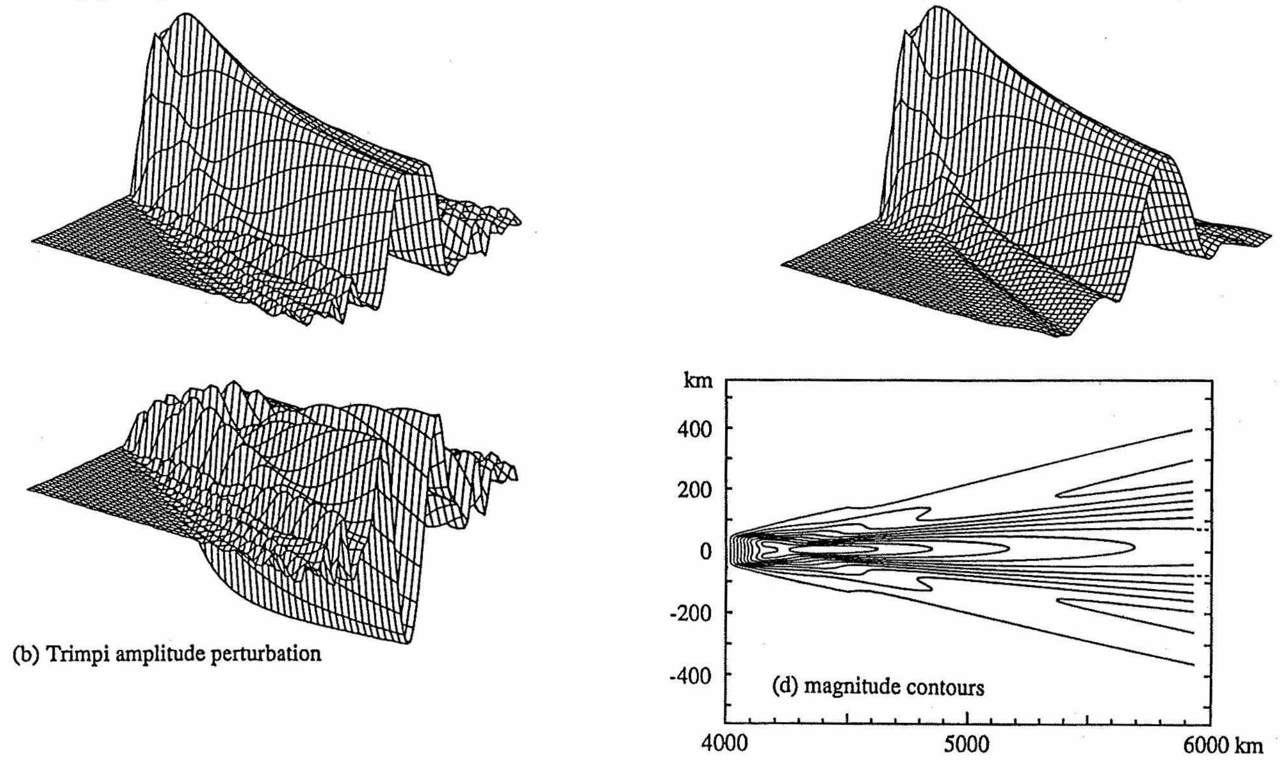
A very recent discovery, as yet unpublished, is that another form of lightning-induced ionisation enhancement (LIE) is produced coincident with the lightning (i. e., without delay) but which decays in a much shorter time (~ 1 second) implying that it is formed at much lower altitudes than the LEP produced LIE. This rapid onset, rapid decay (RORD) LIE is often produced by the same lightning as is LEP produced LIE. If both types of LIE occur in the same location (or merely in the same Fresnel lane [2]) this would appear as the "early' or "fast" Trimpi first described by Armstrong [3].

A VLF receiver placed down wave of the LIE (whether LEP produced or RORD LIE) will see the wave from a phase-stable transmitter as perturbed in amplitude [1] and in phase [4] depending on the receiver position within the diffraction pattern [2]. If the transmitter, LIE and receiver are in line (same great circle) then the phase perturbation is positive (phase advance) and the amplitude perturbation is negative (amplitude reduction). The relative sizes of these two perturbations depends on the altitude distribution of the LIE [5] but not so much as to change the signs of the phase and amplitude perturbations. If the receiver is laterally displaced from the transmitter-LIE great circle, the perturbation signs change progressively and cyclically with increasing lateral displacement in the order: + – (phase and amplitude, respectively, at zero receiver displacement); + +, – +, – – + – (again, after completing one cycle), and so on. The first repeat of positive phase, negative amplitude perturbation (+,–) occurs when the transmitter – LIE – receiver distance is one wavelength longer than the transmitter – receiver distance (direct path).

A sufficiently long and dense array of VLF receivers arranged transverse to the transmitter–LIE line would see all these perturbation combinations provided the diffraction pattern of the LIE is wide enough. This width depends on both the lateral size and the lateral ionisation distribution of the LIE — a Gaussian distribution giving the least diffraction spread. In fact, if the details of the diffraction pattern are adequately measured by such an array by receivers, the shape (lateral variation in ionisation enhancement) and position of the LIE can be determined by the VLF equivalent of holography [2].

Each VLF receiver measures both the amplitude and phase perturbation of the subionospheric transmission from one of more VLF transmitters (most of our research uses the single transmitter, NWC, situated nearly 6,000 km west of our array in N.Z., and which radiates 1 MW at its current frequency of 19.8 kHz). Even the relatively slow (~1 s) onset of "Trimpi" perturbations is quite adequate for precise measurement of the amplitude and phase (relative to an arbitrary but stable standard) of the unperturbed transmission. By phasor subtraction of this unperturbed transmission from the perturbed one, we can determine the phase and amplitude of the wave scattered by the LIE. This concept (scattering or diffraction) is also valid if the transmitter, LIE and receiver are in line (same great circle). When the LIE is also laterally extensive this diffraction approach gives the same answers as the "geometric" approach which considers only propagation along the transmitter–LIE –receiver great circle path.

The converse, however, is not true. Figure 1 shows the amplitude and phase perturbation expected from a square LIE corresponding to a uniform ionospheric depression over a 100 x 100 km area, aligned NS and EW, from a VLF transmitter placed 4000 km due west of the western edge of the LIE. This means that the wave phase velocity in the Earth-ionosphere waveguide is constant within this rectangular region (100 km E-W by 100 km N-S) but is slightly higher (due to the depression of the effective height of reflection) than that outside this region. A receiver placed anywhere in the horizontal area covered by these mesh plots would experience the perturbation indicated by the vertical displacement of the mesh. Note that the perturbation shadow or downwave "wake" is much wider than the geometric shadow which would apply for vanishing small wavelengths. The width of such a geometric shadow is indicated by the short dashed lines at the right hand end of the contour plot



(a) Trimpi phase perturbation

(b) Trimpi amplitude perturbation

(c) Perturbation magnitude

(d) magnitude contours

Fig. 1. Perturbation "shadow" (or "wake") cast by a square LIE corresponding to a uniform ionospheric depression over a 100 x 100 km area, aligned NS and EW, from a VLF transmitter placed 4000 km due west of the western edge of the LIE. The shadow is calculated out to 6000 km beyond this edge in the direction of the unperturbed waves (eastward) and about ± 500 km laterally (NS). The mesh plots are viewed from the south west. The vertical dimension of these is (a) the Trimpi phase perturbation in deciradians, (b) the percentage amplitude perturbation and (c) the perturbation "magnitude" which is approximately (for small perturbations) proportional to the square root of the sum of the squares of the phase and amplitude perturbations. This magnitude is also contour plotted in (d) to show the perturbation immediately under the ionospheric depression (first 100 km of the shadow). The dashed lines at the extreme right of (d) indicate the edges of a purely geometric shadow.

(Figure 1 d). Within such a geometric shadow the perturbation would be a uniform one of phase advance and essentially no amplitude variation. In the real situation of VLF waves, Figure 1 (a) and (b) shows that both amplitude and phase perturbation is produced even though the ionospheric depression produces only an increase in phase velocity. Note also that receiver sites of maximum phase perturbation are those of zero amplitude perturbation and *vice versa*. Such strange behaviour to one thinking in terms of geometric optics is easily understood as the phasor addition of the unperturbed and scattered waves.

Figure 1(c) shows the magnitude of the signal scattered by the square LIE. This could be regarded as the "diffraction shadow" of the block. The cross section of the shadow at any range from the LIE represents the diffraction pattern. If, on the other hand, the LIE is circular and if the radial distribution of the ionisation enhancement (and so the amount of propagation perturbation) is Gaussian, the cross section of the diffraction shadow at all ranges is Gaussian. Antenna engineers will recognise this as the equivalent of a broadside array having a tapered (Gaussian) feed to suppress sidelobes while the rectangular block LIE corresponds to a uniformly fed array. Theorists frequently use this Gauusian LIE model [5, 6] because it looks "natural" and because of its convenient transform properties, but these very properties of minimum diffraction spread and fine structure set it apart as an extreme not necessarily met in real LIEs.

So far, our VLF antenna array has consisted of only five elements arranged broadside (north-south) to the transmission from NWC (approximately west to east). Each element consists of antenna, preamplifier and receiver. The unperturbed signal from NWC provides the phase reference for each of these so in that sense the array is coherent. Four or the elements span only 50 km and are spaced in multiples of $3\lambda/4$ so that the phase of the LIE–scattered signal, relative to the unperturbed phase of NWC, can be compared from element to element without ambiguity (folding over 2π). If the LIE is in the same direction as NWC the scatter phase is the same at each element. If the LIE–scattered signal comes from a different direction, the resulting linear variation of scatter phase along the array enables the direction of arrival to be determined. The fifth element is nearly 600 km further away, too far for scatter phase measurement but useful as an indication of the width of the diffraction pattern.

Data from this limited array lead to the identification of the rapid onset, rapid decay (RORD) perturbation which might otherwise have been dismissed as a broadband sferic instead of a very short duration (~1 s) echo of the NWC signal. Apart from our verification of the echo nature of the RORD perturbation, our conclusions [7] from the use of the present array refer only to the conventional "Trimpi" perturbations produced by LEP LIEs. For these we find that the diffraction pattern is frequently wider than 600 km though the centre is usually near or even north (equatorward) of the northern end of the array. Directions of arrival measured on the four elements at the southern end are usually north of the direction of NWC, which also indicates that LIEs occur typically at lower latitudes than Dunedin (~45° S). Although the number of elements is inadequate to determine the shape of the diffraction pattern, two things are clear. Firstly, Gaussian LIEs sufficiently compact to produce the wide diffraction patterns would not be strong enough scatterers to produced the perturbation magnitudes observed. Secondly, deep nulls sometimes occur in the diffraction pattern implying sidelobes like those in Figure 1 which are clearly inconsistent with Gaussian LIEs. Such nulls are only observable if they fortuitously occur on one of the three middle elements, so such non-Gaussian LIEs are probably common.

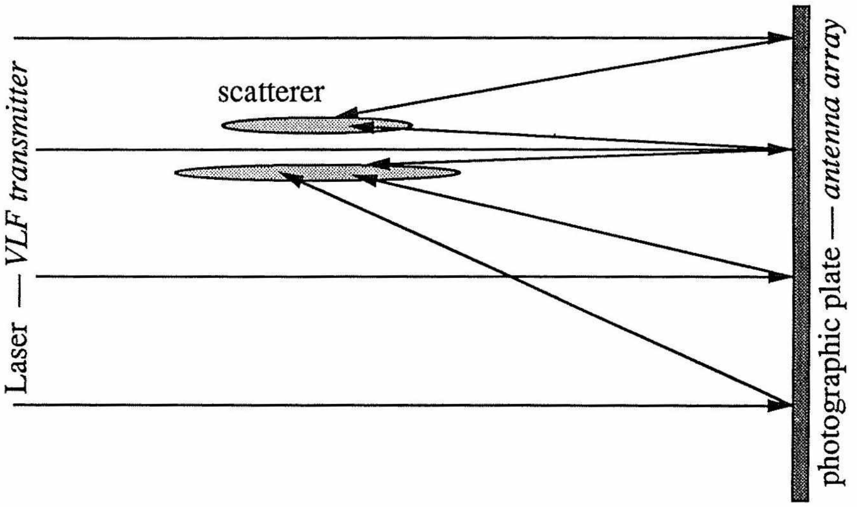


Fig. 2. VLF holographic reconstruction based on that of its optical counterpart. The optical items are labelled in ordinary type while the VLF counterparts are labelled in italics. During VLF "exposure" both phase and amplitude perturbation is recorded while in the optical case only the amplitude perturbation is recorded. For reconstruction, the phase standard (the laser in the optical case) is not required in the VLF case.

Our guess is that LIEs are the footprints of whistler ducts, sometimes of two or more ducts simultaneously. Such ducts would be arrayed in latitude (north-south) but probably elongated east-west. Such a "venetian blind" array of LIEs would produced pronounced grating-like diffraction effects for east-west propagation but relatively little for north-south propagation.

VLF Holography

To get an adequate VLF holographic image of the electron precipitation pattern, we need a longer array and many more elements. We are presently building a 30–element broadside array spanning some 500 to 1000 km along the length of New Zealand with outlying individuals in Australia. The VLF receivers are digital and software intensive, and fit on a standard sized board for running in a low end personal computer (PC). From previous experience, amateur radio operators ("hams") are happy to participate in such experiments and can often provide their own PCs. The cost of such an array is almost proportional to the number of elements but almost independent of the element spacing and so the total length of the array. As we will see below, increasing the spacing increases the resolution but also increases the spurious responses.

The principle of VLF holographic reconstruction is basically that of its optical counterpart as depicted in Figure 2. The optical items are labelled in ordinary type while the VLF counterparts are labelled in italics. There are some important differences, however. In the optical case, the 3-D holographic image is produced from the 2-D interference pattern on the photographic plate. In the VLF case, the 1-D pattern of amplitude and phase sampled by the array produces only a 2-D (geographic) image. In the optical case, the dimensions of the photographic plate are some 200,000 wavelengths compared with some 30 to 100 in the VLF case.

For the first two simulations to be shown, a uniform array of 31 equally weighted, equispaced elements is used. The amplitude and phase of the signal scattered from a point scatterer is calculated for each element in the array. This produces a diffraction pattern sampled by the array and so the 1-D hologram we need to reconstruct the scatterer (a point one, in this case). For this reconstruction the roles of the 31 elements are reversed, meaning that each one is notionally supposed to radiate a VLF wave of the phase and amplitude

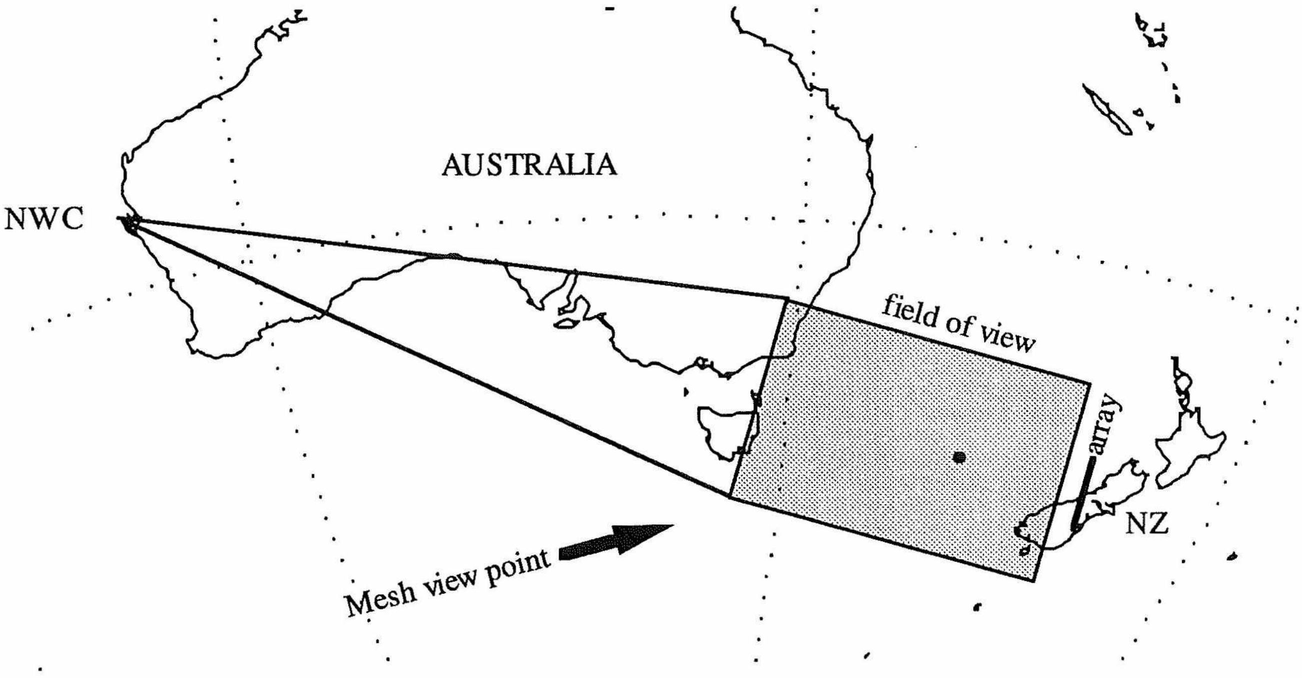


Fig. 3. The field of view (1800 x 1200 km) of the VLF holograph show in the mesh plot reconstructions (e.g., Figure 4 below) is shown above as the gray rectangle. The thick arrow shows the viewing direction of the mesh plots below. The point scatterer is the circular spot 600 km from the eastern edge. The VLF antenna array (thick line over NZ) is the 450 km one appropriate for Figure 5. For the other two mesh plots the array length is three times this length. In practice, the array would be arranged along the axis of New Zealand and the elements would be sited conveniently and so not exactly broadside or linear or evenly spaced.

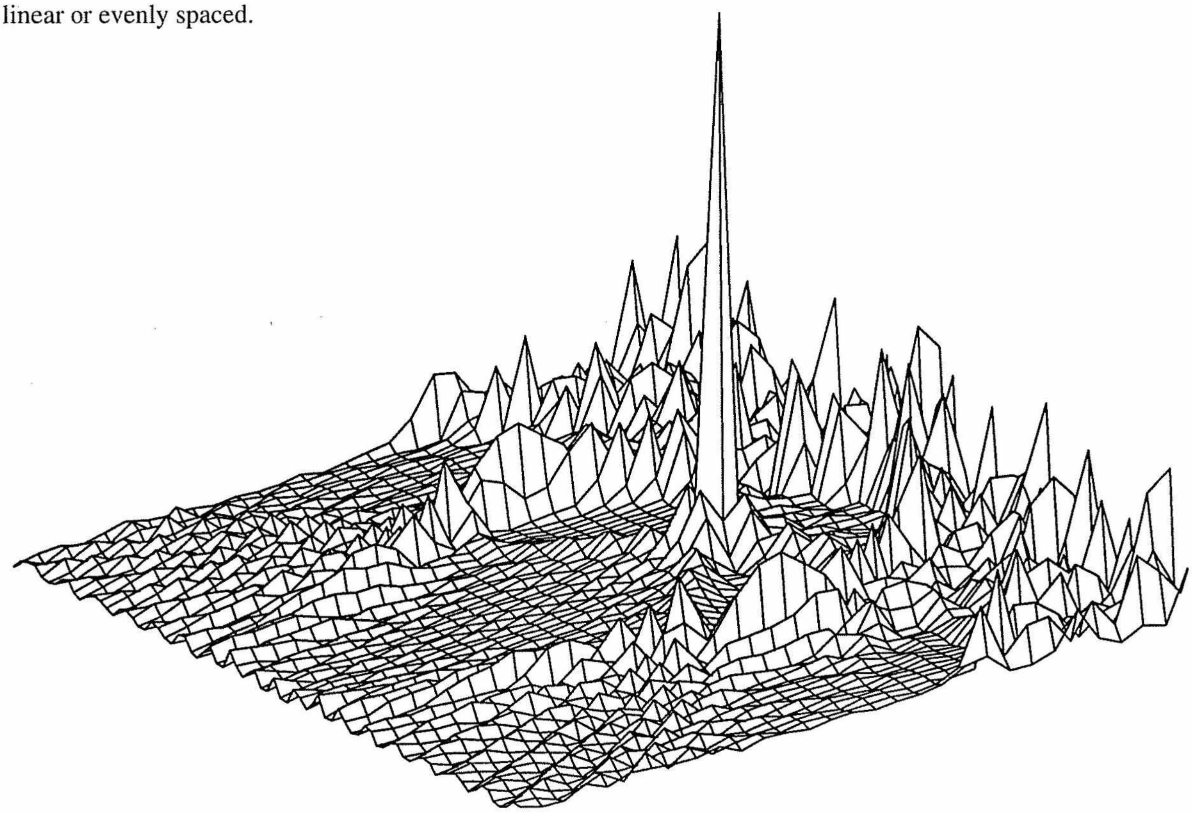


Fig. 4. Mesh plot of the wave field power deduced in 2-D holographic reconstruction from the 1-D diffraction pattern along the array. Power is the vertical dimension. The horizontal dimensions span the field of view shown in Figure 3 above. In this case, there are 31 elements spaced 3λ (45 km) apart to produce a total array length of 1350 km. Note the "grass" due to spurious responses. The "east-west" scale differs from the "north-south" (broadside to NWC), so the east-west resolution is worse than it might appear here.

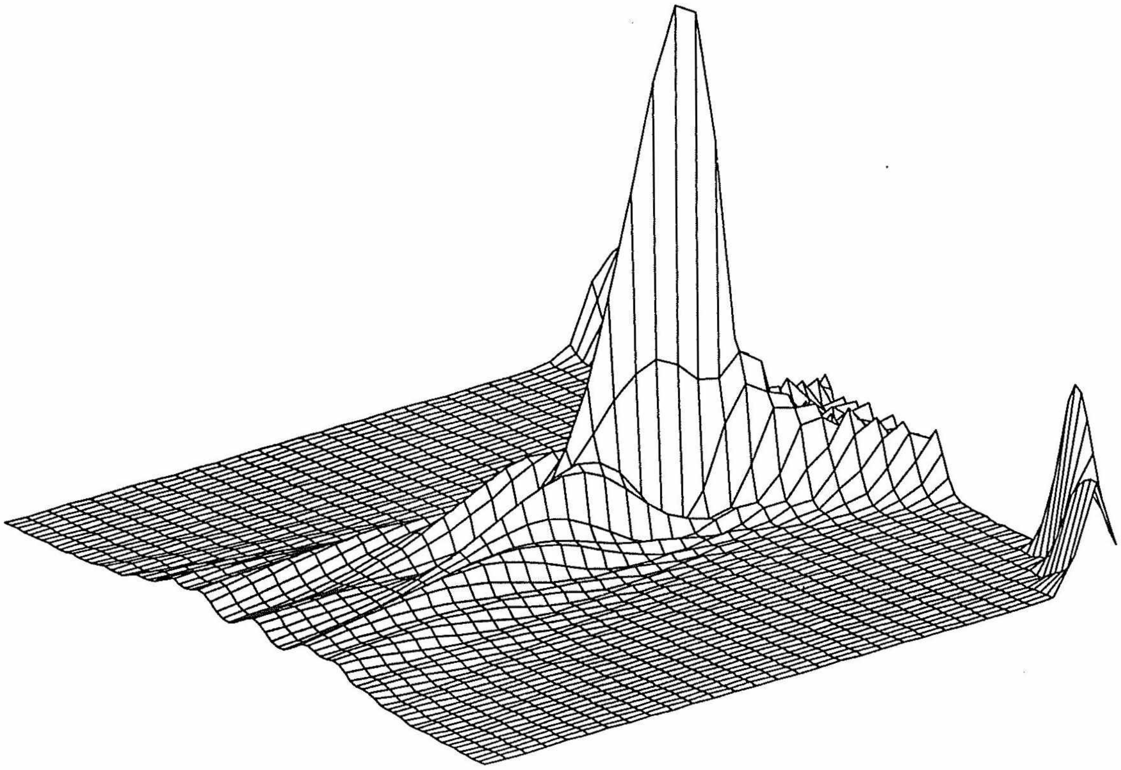


Fig. 5. As for Figure 4 except that the element spacing is 1λ (15 km) so that the array length is 450 km.

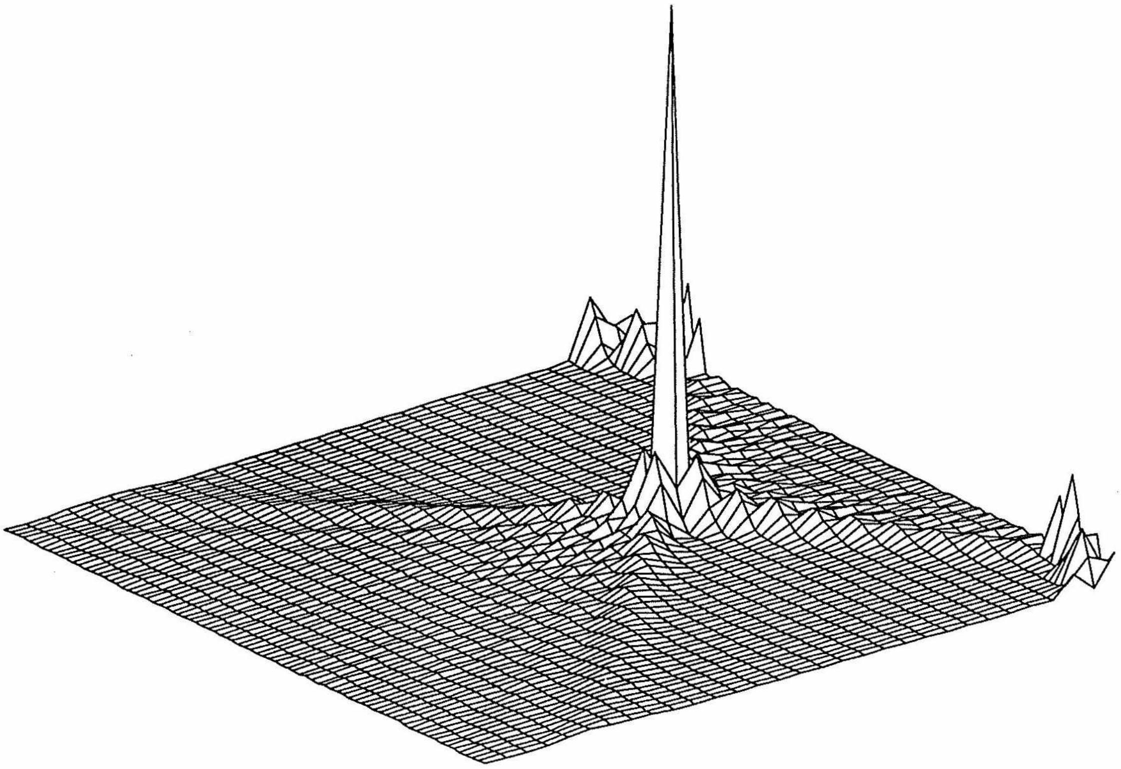


Fig. 6. As for Figures 4 and 5 but using 93 elements spaced 31 (45 km) apart to maintain the array length of 1350 km. This gives high resolution without the "grass" but would cost three times as much.

of the scattered wave it "actually" (but previously calculated in this simulation) received. The mesh plots in Figures 4 and 5 are of the resultant wavefield power obtained by summing the phasor field contributions from the 31 elements. The position of the VLF transmitter is that of NWC (19.8 kHz) as seen from New Zealand and is 3745 km west of the left hand edge. The field of view in these is shown in Figure 3 as the gray rectangle. The borders of the field of view are not strictly aligned to longitude and latitude because NWC is somewhat north of west. This field of view which corresponds approximately with the Tasman Sea between New Zealand and Australia is a common location for LIEs during the austral winter as determined from our 5-element array (during the summer, LIEs are more common over north western Australia).

The position of the point scatterer (black circle in Figure 3) is more closely determined in azimuth (mainly latitude in this case) than in range (mainly longitude here). This is because the azimuthal position or direction of arrival at the array depends on the linear variation of the received phase along the array, or slope of the wave front relative to the array line, while the range from the array depends on the second derivative of the phase along the array, corresponding to the wavefront curvature. If the scatterer is much further from the array (several times the array length) the azimuthal determination of a point scatterer, or the azimuthal distribution of an extended and structured scatterer (e. g., the footprints of multiple whistler ducts) is well determined while the range information is largely lost.

In an attempt to regain the range resolution the elements are spaced by 3l (about 45 km) for the simulation calculated for Figure 4. For such an array of length 1350 km (90l), the range at which the far field becomes dominant is about the circumference of the Earth and so well beyond the transmitter! For the much shorter ranges in the field of view shown, the near field dominates. The array diluteness gives rise to an unacceptable level of spurious responses or "grass" although the resolution of the point scatterer (largest spike near the centre of the field of view) is well resolved. For Figure 5 the element spacing is reduced to 1l (15 km). This removes the grass-like spurious responses of Figure 4 but the longitudinal (east-west) resolution is very poor, and even worse than it might appear because the east-west span of the field of view is 50% larger than the north-south span. There are high angle or sidelobes in the top and bottom corners of the field of view, but these could be removed by low pass filtering the diffraction pattern in amplitude and phase as sampled by the array elements. Since all such processing is done off line, several forms of processing can be used for any event. For three times the cost (93 elements) we could have both the high resolution (1350 km array length) and a low level of grass (15 km spacing of elements) as shown in Figure 6. In practice, the array would have to lie along New Zealand to fit it on land, but this would have little effect on the resolution.

Applications

Although the incentive for developing this holographic technique was for the location and imaging of lightning-induced electron precipitation, our VLF array can be used for locating regions in which the VLF propagation velocity and/or attenuation is changing by whatever cause, provided the change is measurable. If the change and return to normal is fast, as is the case for RORDs, quite small changes are measurable. The time scales (onset and decay) for classic Trimpis are longer by an order of magnitude which means that larger changes are needed for measurement.

Another form of propagation anomaly is the "seismo-Trimpi" thought to be an earthquake precursor (see page 73, this issue). If so, large arrays for VLF holography should be able to locate the geographic position of the subionospheric propagation anomaly and so that of the immanent earthquake. The low attenuation and high phase stability of subionospheric propagation suggests that a relatively small number of such arrays could monitor the whole Earth. This is particularly relevant in the **Decade for Natural Disaster Reduction** in which URSI will be taking part.

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HF Communications - Science and Technology

by John M Goodman. Van Nostrand Reinhold, 1992. ISBN 0-442-0015-2 632 pp, $74.95.

At last we have an "encyclopedic" treatment of the theory and practice of HF Communications by one of its long-time practitioners, Dr John Goodman of the US Naval Research Laboratory (NRL) in Washington, DC — one of the US Navy's foremost Labs. Although the author's perspective comes from the military milieu, most of this book can be read profitably by anyone seriously interested in HF communication. It comes close to telling us "everything we ever wanted to know" about the subject. It is a well-organised, very readable book written in a lively, absorbing, fascinating style, and the typography, figures and tables are excellent.

The preface is especially valuable to those who wonder why and how HF Communication should be used — the author does a good job delineating the "myth vs the realities" of HF. Each chapter is also succinctly summarised for the reader. Many readers skip the preface of a book, but this preface is meant to be read — those who make the decisions on research and use of HF radio should *especially* read this preface!

The first chapter starts with a concise seven page historical account of HF radio development and ionospheric studies. In this section, Goodman describes the "interweaving" of the disciplines of geomagnetism, solar and auroral observations, Maxwell's theoretical studies, Hertz and Popov's experiments, and Marconi's demonstrations of the propagation of radio waves via the "Kennelly-Heaviside" layer.

The experiments of Appleton-Barnett and Breit-Tuve, the Appleton-Hartree magnetoionic equations and the remarkable advances in theory and techniques for studying the ionosphere from 1925 until 1940 are also covered. The remainder of Chapter 1 covers the "current utilisation of HF", propagation modes, "trials and tribulations of HF" and some solutions to the problems. The section on OTH systems uses the term, "splashback" — a very colourful term for ionospheric backscatter.

Chapter 2 gives a remarkably complete overview of the "Solar-Terrestrial Environment"; from the centre of the Sun, through interplanetary space, into the earth's magnetosphere and ionosphere. Long and short-term solar activity and the effects upon the ionosphere — as well as an outline of the present prediction services is also covered. The References and Bibliography for this chapter are complete enough for the topic of the book. As in all books, there are a few "typos", such as the misspelling of Gillmor's name in the bibliography on page 31.

"The Ionosphere and its Characteristics" is the title of Chapter 3 in which the author describes ionosphere formation, properties, regions, anomalies, solar influence and ionospheric storm behaviour. The section describing the four ionospheric current systems is especially succinct, but the subsection on the high-latitude current system, neglects the work done on this topic since 1972 — i.e. that an essential component of the auroral electrojet is the increased E-region conductivity caused by auroral particle precipitation, as pointed out most recently by Kamide (1990). Also, Figure 3-23 on page 133 portrays the oval incorrectly in the western north American and Siberian sectors. Ionospheric models are discussed adequately in Section 3.8 (12 pages) and predictions are discussed briefly.

Chapter 4 (the longest, at 132 pages) covers "HF Propagation and Channel Characterisation" in exquisite detail. Topics included are: field strength, power density, polarisation, attenuation, reflection, refraction, diffraction, fading, scattering, dispersion, Doppler shift and spread, and group path delay. The section on groundwave (surface wave) propagation (4.4.2), including propagation over irregular terrain, is especially good. There is a short but reasonably complete exposition (Section 4.5) on the Appleton-Hartree equations and "sky-wave" propagation. There is an error in equation 4.5b on p.201 — a large "left-bracket" is missing in the denominator of the equation, and this reviewer wishes that the author would have used SI units throughout! A good discussion of radiowave polarisation and Faraday rotation is given in Section 4.5.1.

A short section (4.6) on "Near-Vertical-Incidence-Skywave (NVIS)" propagation mode is included, and although this mode is primarily used by the military, there are some civilian applications. This mode is primarily used when there is very thick vegetation or a hill between the transmitter and receiver — thus precluding conventional VHF through microwave line-of-sight communication. An extensive list of references is included at the end of the chapter.

The remainder of Chapter 4 is devoted to oblique-incidence skywave propagation which is, of course, the dominant HF propagation mode. The first four pages of this section gives a rather complete listing of the definition of terms used by communicators at HF, the relation between vertical and oblique propagation, ray tracing through the ionosphere, multipath and fading, channel modelling and simulators. Mitigation of the effects of HF multipath propagation various diversity techniques is a valuable section for HF communicators.

Chapter 5 describes "Performance Prediction Methodologies", generally defined by the author as "hindcasting, nowcasting, (short-term) forecasting and (long-term) predictions". The reader is provided with a general summary of the attributes of major models, a section on small computer programs and on-going efforts for improvement in long-term predictions, concluding with comments on international cooperation.

Chapter 6 is the second longest chapter in the book and deals with "Real-time channel evaluation (RTCE)", sometimes called "nowcasting". Specific RTCE classes include; oblique-incidence sounding (OIS), channel evaluation and calling (CHEC), vertical-incidence sounding (VIS), backscatter sounding (BSS), frequency monitoring (FMON), pilot-tone sounding (PTS), and error counting systems (ECS). Each of the foregoing RTCE classes are discussed in considerable detail.

Methods of solving some HF propagation problems are given in Chapter 7 on "Adaptive HF and the Emerging Technologies". The author points out that although "Adaptive HF" has been discussed for several decades, it was not until the technological advances starting in the 1970's, that actual systems were studied, culminating in the 1980's with actual system implementation. The complexity of "adaptive HF" is emphasised by the fact that the author uses 9 pages (Section 7.5) to properly *define* the subject! For instance, Goodman specifies 4 types of adaptability; transmission, link, network and system — most of this discussion, however pertains to military applications. An "encompassing definition" of "HF adaptable systems" is given by the author as, "any HF communications system that has the ability to sense its communications environment, and, if required, to automatically adjust operations to improve communications performance."

Chapter 7 includes 44 pages (Section 7.6) on "Technology: Foundation of Advanced/Adaptive HF", in which the author presents the results of the numerous technological advances made since the early 1980's, and their special applications to HF systems. Specific areas where significant advances in technology have been made are in: solid-state power amplifiers, receiver and transceiver design, antennas and couplers and modulation techniques. He concludes Chapter 7 with a good "Sampling" of adaptive systems in use (Section 7.7) and "Strategic" (military) HF adaptive systems (Section 7.8) and a 10 page reference list.

In the "Epilogue", the author briefly summarises the state of modern HF communication systems and indicates areas where some improvement can be made. The book has relatively few "errata" but my copy was missing the index from the middle of the "T's" to the end.

This book should definitely be in the possession of anyone with a serious interest in HF Communication and propagation!

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The Electrical Engineering Handbook

edited by Richard C Dorf, CRC Press, Boca Raton, Florida, 1993, 2662 pages, ISBN 0-8493-0185, US price $89.95.

As indicated in the preface, this massive document, in a single binding, is intended to provide a ready reference for the practicing engineer in industry, government and academia. The book is divided into twelve sections which encompass the whole field of electrical engineering. The ultimate goal is to signal processing, electronics, energy devices, systems, telecommunications, computers, and biomedical engineering. There are a total of 109 chapters averaging about 25 pages each but varying widely in scope and length. The writing tasks were shared by 250 authors. Each author provided anywhere from one to thirty or more literature references for further detailed information. Curiously, cross-referencing between individual chapters was absent although the uniformity of the prose and the illustrations was good.

The inevitable comparison is with the illustrious *Handbook of Physics* edited by Condon and Odishaw published by McGraw Hill over 30 years ago, revised and reprinted many times since. My general impression is the Electrical Engineering Handbook does not have the same continuity in the coverage which might be attributed to the fewer number of authors and the greater emphasis, in the Physics Handbook, on basic principles. But the handbook under review wins hands down on providing ready-to-use data for design of actual systems.

This reviewer does not feel inclined nor qualified to give an overall evaluation of the technical merits of each chapter. But on perusing chapters, where I had some familiarity with the subject matter, I came across a number of lapses, omissions and annoying misprints. For example: on page 908, the electromagnetic shielding formulas do not specify clearly what their limitations are; on page 983, the field solutions for the graded index fibers are not exact solutions of the scalar wave equation although they may be good approximations for the purpose at hand; on page 1370, the definition of ERP (effective radiated power) is vague and apparently incomplete because it does not account for the all important ohmic losses in the ground in the vicinity of the broadcast antenna; on page 977, eqns 40.5c and d are incorrect as written, obviously they should be div $\mathbf{E} = 0$ and div $\mathbf{H} = 0$; also there is a sign error in eqn 40.7; on page 1219, the 1926 equations of Carson are only approximate and will be inadequate for higher frequencies for radio transmission over power lines for resistive soil (here the mixed units of feet and meters are unfortunate). But these are relatively minor shortcomings. All in all, I would say the customer is getting a real bargain, on a cents-per-page basis, in making such a purchase.

James R. Wait, Review Editor

Wave Physics, Oscillations-Solitons-Chaos

by Stephen Nettel, Springer-Verlag, Berlin, London, New York, etc. ISBN 3-540-55715-6, 1992, US$39.00, 244 pages, hard cover.

This relatively slim book written by Professor Nettel is a pleasure to read. The author's hope, that the book will be of use to undergraduates in Physics and of interest to others such as professors looking for exam problems, will certainly be met. The presentation is a very nice blend of mathematical rigor, physical understanding and real world examples. Exercises are sprinkled throughout the text. They should be particularly suitable for honour undergraduates in physics who plan to go on to postgraduate research. In fact, I would think the material would be highly suitable to test the more robust engineering undergraduates and help offset the recent trends, imposed by curriculum committees, to attenuate basic physics courses in favour of computer-oriented design courses with little physical insight gained.

The bulk of the book deals with the classical development of the physics of waves in a linear setting. The mathematics is handled at a somewhat higher level than would be expected for undergraduates but the informal and engaging style is guaranteed to maintain the reader's interest whether he or she is a fresh bright student or a mature researcher. The latter would greatly benefit from even a casual reading as this reviewer will attest.

The specific topics considered are : Mathematical foundations including a nice introduction to generalized functions, Natural motions and oscillations, Waves on stretched strings, Maxwell's equations and vector potentials, Physical optics and diffraction and refraction, Wave mechanics and the wave-particle duality and the loss of determinism, Linear and nonlinear surface waves on water, Solitons, Inverse scattering, Chaos and order, and Fractals. These latter (nonlinear) topics were covered mainly by Professors A V Gaponov-Grekhov, M I Rabinovich and M C Gutzwiller.

At the price indicated, this is a good buy at least compared to other recent books on similar topics from other publishers not named here.

James R. Wait
Review Editor

Spatial Dispersion in Solids and Plasmas

edited by P Halevi, Elsevier Science Publishers, 1992, xiii + 681 pages, 305.00 (Dutch) Guilders, US$180 (approx), ISBN 0-444 87405 4.

This is Volume 1 of a new series on *Electromagnetic Waves: Recent Developments in Research.* According to the editor, review articles, to be published in this book series, will cover new developments in research on electromagnetic wave phenomena. The material to be considered will include such things as waves in transparent crystals and glasses, semiconductors, metals, plasmas, and liquids. The wave propagation may occur at the surface or in the bulk of the material. The editor Prof Halevi says "the subject will cut across most of the spectrum of electromagnetic waves". It is interesting to note that in this Vol 1 of the newly announced series, there is no mention of the six volumes already published by Elsevier in the series: "Progress in Electromagnetic Research" whose Editor-in-Chief" is Professor J A Kong of MIT. Although the emphasis may be different, there is a notable overlap in the content and scope in these two book series. Indeed, Vol 6 in Kong's series, edited by A Priou†, is entitled "Dielectric Properties of Heterogeneous Materials". It contains many topics discussed in Halevi's Vol 1.

The volume under review here deals with spatial dispersion as opposed to the better known frequency or temporal dispersion. For example, in this latter case, we regard the bulk conductivity and permittivity of the material as a function of frequency which, in the time domain, leads to a convolution integral description. That is, the transient response, at a time t, depends on the prior history of the event. Thus, it would be inappropriate to say that the conductivity is a function of just t. In the case of "spatial dispersion", the conductivity and permittivity depend on the wave vector of the excitation in the spatial spectral domain. In the corresponding real space domain, the response is then expressed in terms of convolution integrals over dimensional variables. In other words, the response, at a point P, depends not only on the excitation at that same point, but also at neighbourhood points. Such non-local effects play a role in a wide range of known physical phenomena such as : rotation of light in anisotropic crystals, coherence length in super conductors, the anomalous skin effect in metals, collisionless damping in plasmas, "additional" waves in semi-conductors and excitation of longitudinal plasmons in thin films. The reviewer could also add to this list taking examples from classical electromagnetics. The first one that comes to mind is the averaged boundary condition or effective surface impedance for a wire mesh screen. The presence of tangential derivatives of the field quantities is a manifestation of spatial dispersion.

The volume has a very readable introduction (109 pages), by Fuchs and Halevi, which presents a unifying view of the subject and it facilitates the comprehension of the following 11 chapters. These authors are : N F Cramer, I J Donnelly, G E Eliasson, R Fuchs, R R Gerhardts, M G Haines, P Halevi, P Hawrylak, E A Kaner, A A Krokhin, T Lopez-Rios, N M Makarov, B G Martin, V T Petrashov, J J Quinn, A Shivarova and R F Wallis (listed alphabetically). The first 10 chapters deal explicitly with electromagnetic wave (polariton) propagation in the bulk, at surfaces, in thin films and superlattices, in spheres and on cylinders. Chapter 11 deals with laser-induced inertial confinement fusion and specifically nonlinear and non-local heat flow.

The book, as a whole, is clearly directed to researchers in solid state physics but electromagneticians of the URSI ilk would benefit greatly from the contents particularly the excellent summarising introduction by Professors Fuchsia and Halve. Also the 11 supporting chapters all contain important material relevant to scattering from non-ideal targets. For example, the chapter 5, by Fuchsia, entitled "Theory of Spatial Dispersion in Small Particles", deals with the non-validity of Mie-Lorenz theory when the radius of the particle is of the order of 50 Angstroms.

Apart from its sheer size, the book is attractively produced. The illustrations are exceptionally well done with very clear labelling. The literature reference lists are extensive (but article titles not given). Only a few references are later than 1987. The price is high but institutional libraries at major industrial and academic canters should consider it a worthy purchase. Most individuals will have to wait for the hoped-for paperback edition.

James R. Wait
Review Editor

Nonlinear Optics

by D L Mills. Springer Verlag, Berlin, Heidelberg, New York (1991).

The field of nonlinear science, which has come of age over the past decade, is to some degree floating free of its roots. Problems of technical interest to the practitioners abound and often dominate the pages of conference proceedings, research monographs, and even textbooks. Thus it is a pleasure to read *Nonlinear Optics* By D L Mills, which discusses solitons and chaos but remains firmly within the context of the optics laboratory.

Subtitled "Basic Concepts" this book includes within its 184 pages clear descriptions of both linear and nonlinear dielectric response, harmonic generation, wave mixing and Raman scattering. Even without the discussions of solitons and chaos it would be a useful introduction to modern optics, but Chapter 6 on self-induced transparency and its relation to the sine-Gordon equation sets the tone for a much broader picture. Chapter 7 considers wave propagation on optical fibers in relation to the ubiquitous nonlinear Schrödinger equation, solitons of which are probably the most important fruits of nonlinear science. A final chapter introduces the concept of chaos in relation to Duffing's oscillator and briefly describes some experimental observations of chaos in the optical laboratory.

With two appendices, thirty-two figures, and problems at the end of each chapter, **NONLINEAR OPTICS** is an ideal text for a senior or introductory graduate level course in modern optics. It should also be of value to the research scientist who wishes to get a balanced view of the important field.

Alwyn Scott
The Technical University of Denmark

Acoustics of Layered Media 1992

Part I: Plane and quasi-plane waves by L.M.Brekhovskikh and O.A.Godon (both at the Shirshov Institute of Oceanology, Moscow), , 240 pages, 44 figs., hardcover, ISBN 0-387-51038-9, US$83.00.

Part II, Point source and bounded beams, 395 pages, 42 figs., hardcover, ISBN 0-387-52646-3, US$89.00

These are vols 5 and 10 of the Series on Wave Phenomena published by Springer-Verlag, New York and Berlin. People who are familiar with Brekhovskikh's "Waves in Layered Media" (Academic Press, 1st Ed. 1961 and 2nd Ed. 1980) will find considerable similarity with these Parts I and II published as separate books. The emphasis is now on scalar acoustic wave propagation with particular applications to underwater sound phenomena. But the methods are clearly relevant to electromagnetic waves at high frequencies where the vector nature of the fields do not play a crucial role. The authors do deal with elastic waves in solids but the direct correspondence with electromagnetic waves is not simple.

In Part I, some of the topics treated are: plane waves in discretely layered fluids, moving media, reflection from special profiles such as the Epstein layer, Airy functions and their use for dealing with general graded profiles and critical reflection, reflection from boundaries between liquids and solids, matrix propagators, reflection of sound pulses, absorbing anisotropic media, geometrical acoustics and WKB approximations, reflection from a weak interface, and a critical look at the Born approximation.

In Part II, the subject matter can be read and understood without reference to Part I but this reviewer suggests that it helps to have the earlier volume at your finger tips and maybe also "Waves in Layered Media". Topics in the second volume include: spectral representation of a spherical wave, more on weak boundaries, bounded beams and total reflection, Goos-Hanchen shift, lateral waves including the moving media case, directional sources, many "exact" fields solutions, reciprocity and the flow reversal theorem, phase and group velocity of normal modes in various acoustic waveguides, thorough study of caustics and treatment at the cusp, range dependent waveguides and mode coupling, three dimensional waveguides and horizontal ray diffraction effects, the parabolic equation method for dealing with tapered waveguides, and effects of density inhomogeneities on shear waves. At the end of Part II, there is an excellent appendix dealing with the asymptotic evaluation of integrals.

Both volumes have numerous references including those to papers from the Russian (and formerly Soviet) literature but unfortunately titles of the articles are not given. A good feature is the partial listing of the sources for the English translations.

The writing style and the analytical developments are very clear throughout both volumes. I believe these two volumes will be suitable for a graduate level course in applied physics or engineering science but they will be best known and respected as a standard reference on wave propagation theory. However, I will want to keep my well worn copy of "Waves in Layered Media" in spite of the fact there is considerable overlap in the subject matter.

The prices on these volumes are not cheap but they should be affordable by any respectable university library and the individuals who can still make such purchases on their grants or contracts.

James R. Wait
Review Editor

Diffraction Effects in Semiclassical Scattering

by H. M. Nussenzveig. Cambridge University Press, 238 pages, hard back, ISBN 0521 383188, 1992, Price US$60 (approx).

Many will have seen a beautiful article by this author, in Scientific American (vol 236, p.116, 1977) on the basic physics of rainbows, coronas and glories. The simple unadorned explanations of these wonders of nature in that article would make an excellent preface to this book.

A quotation from Lord Rayleigh (the 4th Baron) is in order here: "The full solution of the problem presented by spherical drops of water would include the theory of the rainbow, and, if practicable at all would be a very complicated matter". Professor Nussenzveig had taken up the challenge and published a number of significant and original papers in the mathematical physics journals that may have escaped your notice. Some will say this all looks like resolving the Mie-Lorenz problem of scattering from a dielectric sphere. But such a formal solution given in terms of zonal harmonics is almost useless to bring out the myriad physical phenomena associated with all that happens when the sphere becomes large compared with a wavelength.

The author begins by describing the various critical effects in classical scattering which occur when the standard approximations break down. These are associated with forward peaking, glories, rainbows, orbiting and resonances. Some of the specific topics which follow are: relevant geometrical optics and classical diffraction theory for the corona, wave optics theory for the rainbow and asymptotics, geometrical theory of diffraction and the glory, complex angular momentum concepts and approximations, scattering by an impenetrable sphere and Fock's theory, tunnelling effects and reinterpretation of Fock's formulation, The Debye expansion and higher terms, Regge poles (first discovered by G.N.Watson), the rainbow as a diffraction catastrophe, the forward optical glory, and the complex angular momentum explanation of the "ripple" in calculated Mie scattering patterns. If this isn't enough, the author also discusses applications to radiative transfer, to astronomy, to seismology, to particle physics, and to linear and non-linear optics.

The numerous mathematical derivations are presented in a very concise fashion which explains why the book is only 238 pages. But the author does provide many physical explanations of the results. His keen insight to the subject is very evident in the manner of the presentation which is attractive throughout. Numerous and detailed references are given to the supporting journal literature.

The book is highly recommended to those involved in radio propagation research and radar cross-section studies. Such people are probably not aware of the vast literature on this subject that is not on their reading lists.

James R. Wait
Review Editor

Geophysical field Theory and Method, Part A

by Alexander A Kaufman. International Geophysical Series, Volume 49, Part A, Academic Press Inc., New York, 60 Figures. ISBN 0-12-402041-0 (Vol 1)
Price: US$139 577 pages

The major contribution of this book is the theoretical treatment of several important geophysical problems and methods which have scant recognition elsewhere. These problems include solid angles, geometric field models, the gravity of spherical shells and of one, two and three-dimensional bodies, upward continuation, and various aspects of electric and magnetic fields. Coulomb's and Ohm's Laws form the basis of the electrical chapter. The Biot-Savart Law forms the foundation in the chapter on magnetics. Alternating fields are not considered, but they will be treated in Volume 2 of the series.

The first quarter of the book consists of mathematical developments, followed by a smaller chapter on the gravitational field. The next third of the book is a rather thorough treatment of electrical fields as they are used in exploration geophysics. The final third of the book reviews magnetics in good detail.

Inversion is brought out in the gravity chapter, but is not followed up later. The author consistently uses rigorous analytical solutions of boundary-value-type problems. Geophysical interpretational aspects of geophysical problems is emphasised. Numerical methods are not reviewed; left for treatment elsewhere.

The anticipated reader-level is approximately that of a senior undergraduate or a beginning graduate student, and it is apparent that the book is primarily intended for use as an exploration geophysics text and reference. Many interesting cases and examples are presented, but unfortunately no exercises or problems sets. The level of the book is similar to, but more advanced than, Feynman's 1963 Lectures on *Physics* series with a strong geophysical flavour.

The occasional diagrams are illustrative sketches, without great detail. Sufficient but sometimes overly simplified when applied to the heterogeneous geophysical earth.

The units of the various physical parameters are discussed, which is not always done in this type of theoretical development. The sometimes enormous range in actual earth properties is brought out. Non-geophysicists are made aware of units and physical property matters, because the application of certain theories to real problems may not always be practical.

This is a valuable book in exploration geophysics, and will also be useful to persons in related fields.

John S Summer
Department of Geosciences
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Prof John Summer is the author of "Principles of Induced (electrical) Polarisation for Geophysical Exploration", Elsevier, 1976 which is now regarded as a classic. Professor Summer, and his wife Nancy, died in a plane crash in northern Mexico on June 4, 1993, a few days after I received this review. ***J. R. Wait*****, Review Editor**

† see review in *the Radioscientist* Vol 4, No 1, p26

Note from the Review Editor

If you are interested and willing to review books for the Radioscientist, send me a complete description of the item and the name (and address if possible) of the publisher. Publication dates should be 1992 or 1993. **Of course, you may keep the book after you have fulfilled your commitment.**

Mail reply to:

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USA.

Fourth International Conference on Ground Penetrating Radar (GPR)

8-13 June, 1992, Rovaniemi, Finland, Geological Survey of Finland Special paper 16. ISBN 951-690-463-7, GSF Pub. Sales, SF-02150, Espoo. 490.00 Finnish Marks including postage and handling (365 pages paperback).

This attractively produced compendium of conference papers represents another milestone in this rapidly developing field. As indicated in the preface, the articles were approved for publication "solely" on the basis of abstracts submitted to the scientific committee consisting of S E Hjelt, P Hanninen, J S Mellett and P U Uliriksen. But apparently many of the papers were later edited by Pauli Hanninen and Sini Autio. There are 45 articles representing contributions from the international community of GPR investigators. The general topics are : Geological applications, civil engineering applications, instrumentation and related research investigations mostly of an experimental nature. Much attention was paid to data processing techniques. There are also many case histories which are accompanied by colourful and clear illustrative examples such as direct plots of sub-surface time delays versus lateral displacement along the surface.

It is apparent, at least to this reviewer, that this is a subject where theory greatly lags the experimental techniques. While it is true, much useful information can be gleaned from the observed data, it seems that quantitative understanding and further insight will come from analytical studies of such things as allowing for the dispersive nature of the transmission medium such as caused by the appropriate frequency dependence of the conductivity and permittivity of the medium. Also it seems that people working in this field have not exploited or even are aware of the vast literature on the use of transient electromagnetic waves in mineral exploration such as reviewed in considerable depth in the Special Issue of *Geophysics* (Aug 1984) on the subject "Time Domain Electromagnetics" edited ably by Misac Nabighian. I was also disappointed that there was little discussion of the antenna design which is not a trivial subject because of the close proximity of the radiating structure with the lossy propagation medium. The few papers which did touch on this issue contain material already in the journal literature such as the paper by G A Burrell and L Peters in the Proc. IEEE July 1979 Special Issue on "EM applications in geophysical exploration" edited by this reviewer.

It is a pity that none of the discussions of the participants at the meeting are summarised in this document. Nor were there any substantive review or summarising papers in the publication.

In spite of the indicated shortcomings noted above, I believe workers in the field will need to have access to this publication. The price is high but not outrageous (i.e. approximately US$100).

James R. Wait
Review Editor

Seismic–VLF Effects

The subionospheric propagation of Omega VLF signals transmitted from Hawaii and received in Japan, has been utilized to find the seismic effect (seismo-Trimpi effect). Perturbations in VLF propagation have been identified for some strong earthquakes.

The satellite (Intercosmos-24) observation of ULF and ELF/VLF radio noises in the ionosphere have yielded that ULF waves tend to be observed mainly before the earthquakes and over the subsequent earthquake epicenters, but VLF/ELF emissions appear in a wide longitude range. These characteristics are interpreted in terms of the generation of ULF waves in the ground, their penetration into the ionosphere, and interaction with protons, and the associated proton precipitation.

The seismic effect in whistler propagation has been found by means of the long-term whistler data, and it is found that whistlers with larger dispersions tend to occur as a precursor of earthquakes.

The wave distribution function method has been developed to determine the distribution of wave energy density of VLF waves at the ionospheric base on the basis of the simultaneous measurements of three field components. A very objective method is proposed to yield the most optimum wave distribution function by the combined use of Philips-Tikhonov regularization and generalized cross validation.

Lightning-induced particle precipitation is being studied by using the Trimpi effects detected by subionospheric VLF propagation and the simultaneous direction finding of whistlers. The data were obtained in the VLF campaign in Ceduna in Australia, and the Trimpi data by Professor Dowden.

M. Hayakawa
University of Electro-Communications
Chofu, Tokyo.

[Reprinted from VERSIM, JULY, 1993. There will be an international workshop on Electromagnetic Phenomena related to Earthquake prediction, held in Tokyo right after the URSI General Assembly.]

A Global HF Radar Network for Imaging High-Latitude Convection

Over the past several years, a new international initiative has been started by members of the Dual Auroral Radar Network (DARN) ground-based experiment team of the ISTP/GGS project. DARN was originally proposed to the NASA OPEN mission as a network of VHF E-region coherent-backscatter radars that would provide ground-based measurements of high-latitude convection to complement OPEN satellite observations. As the NASA OPEN mission evolved into ISTP/GGS, the DARN concept also evolved with the development and successful operation of phased-array HF radars such as those located at Goose Bay, Labrador; Halley, Antarctica; and Schefferville, Quebec. These radars require decameter-scale electron density irregularities to be present in the high-latitude E or F-regions for backscatter to be observed. For the dominant F-region observations, these radars have proven to have several advantages over their VHF counterparts. Notably, they have much larger fields-of-view, their Doppler observations are more readily related to F-region plasma drift motions, and there is no apparent velocity threshold for the F-region irregularities to be created.

To this point, most — albeit not all — of the results from HF radars on ionospheric convection have been obtained with single-radar scanning techniques. In this mode of operation, a single radar is pointed into two or more different directions to obtain Doppler information from which velocity vectors can be estimated subject to certain assumptions. For SuperDARN, the HF radars will be operated in pairs and obtain common volume measurements from different viewing directions. This is a mode which has been reported recently using the Goose Bay and Schefferville radars. It is also similar to the operation of the STARE and SABRE VHF radars in Scandinavia and the BARS radars of the CANOPUS network in Canada. Bi-directional common volume measurements yield two-dimensional images of the plasma drift pattern that are based upon *definitive* vector velocity determinations at each location in the common field-of-view for which irregularities are present.

The SuperDARN concept also seeks to expand the observation of plasma drift patterns to a global scale by utilising a network of pairs of HF radars extended in longitude in the northern hemisphere and at conjugate locations in the southern hemisphere. Figure 1 shows the combined fields-of-view of the currently-funded northern-hemisphere elements of SuperDARN. The sites for these radars and their anticipated start of operations are given in the table below.

Location	**Geographic Coordinates**		**Initial Operation**
Saskatoon, Sas, Can.	52.2° N	-106.5° E	Spring, 1993
Kapuskasing, Ont, Can.	49.4° N	-82.3° E	Spring, 1993
Goose Bay, Lab, Can.	53.3° N	-60.5° E	Operational
Iceland West	64.4° N	-22.0° E	Autumn, 1993
Iceland East	TBD		Summer, 1994
Finland	TBD		Summer, 1995

Additional sites in North America are being considered in British Columbia in Canada and at King Salmon, Alaska. However, funding is not currently available for either of these additional sites. Discussions have also taken place with Russian scientists concerning potential sites in their country. While there is no current funding for the Russian radars, it is interesting to consider a northern-hemisphere SuperDARN network consisting of 12 radars, four of which are located in Russia. This scenario is shown in Figure 2.

In the southern hemisphere, there is one HF radar in operation, namely the PACE radar at Halley Station, Antarctic (75.5° S -26.6° E). Two additional HF radars are being proposed; one is a collaborative South African-British-U.S. radar to be located 100 km polewards of the existing SANAE site and the other is a Japanese HF radar to be located at Syowa Station. A plan view of Antarctica showing the fields-of-view of the existing and planned systems is given in Figure 3.

The Principal Investigators (PIs) for the funded elements of SuperDARN and their respective funding agencies are as follows (next page):

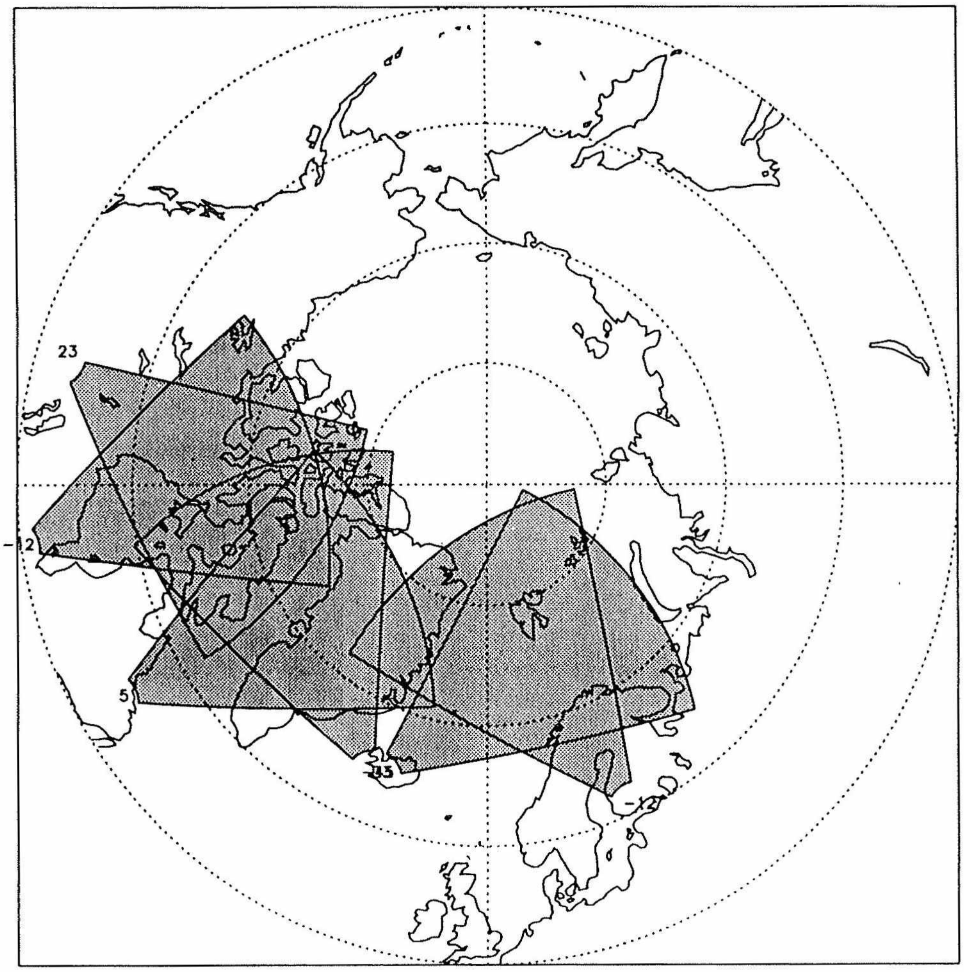

Fig. 1. Combined fields of view of currently funded Northern Hemisphere SuperDARN elements.

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Halley is funded by the Natural Environment Research Council (NERC) and NSF.

The SuperDarn radars will operate continuously providing a global-scale diagnostic of the electrodynamic state of the high-latitude ionosphere. Data from the northern hemisphere radars will be collected at JHU/APL where it will be merged onto high-capacity exabyte tapes and distributed to the PIs in the participating countries for subsequent redistribution to interested scientists. Selected portions of these merged tapes will also be made available to national data centres to support the activities of national and international research programs including STEP. Data will also be processed in real-time at the radar sites to produce Key Parameters that will be submitted to the NASA ISTP/GGS central data handling facility (CDHF) within 24 hours of acquisition. Data from the southern hemisphere radars will be collected at BAS where similar merging and distribution processes will take place. Merging of the full data suites from the southern hemisphere radars will not take place until the optical disks are retrieved from Antarctica, approxi-

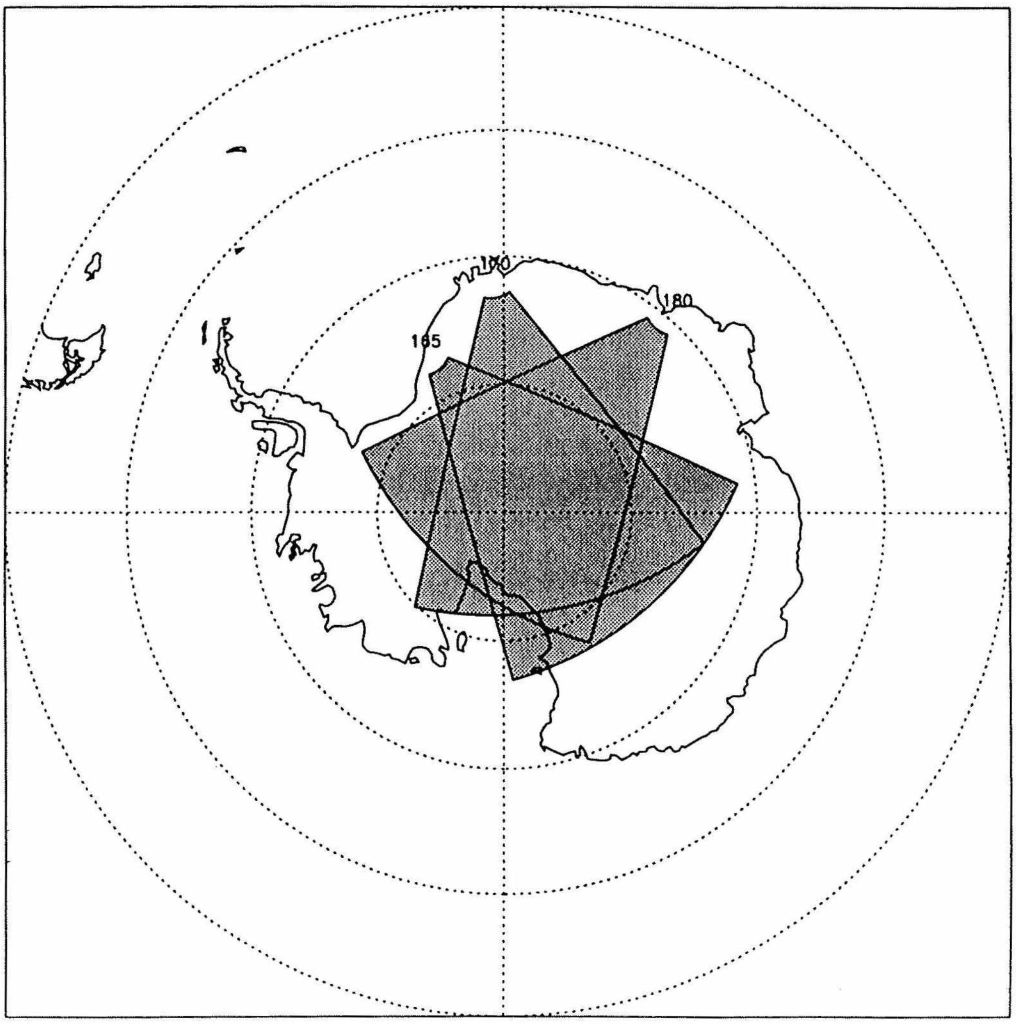

Fig. 2. Plan view of Antarctica with fields of view of existing and planned systems.

mately one year after the data are acquired.

The SuperDARN investigators have identified three categories of operation:

Common Programs: Several standard operating modes of the radars for which all radars will be operated in the same manner. Common programs will comprise 50% of the total operation.

Special Programs: Special operating modes agreed upon by the PIs for the purpose of achieving specific research goals. Special programs will be limited to 20% of the total operation.

Operations: Time set aside for the PIs to pursue personal or collaborative research goals. Discretionary time will comprise the remaining 30% of the radar operations.

Over the past several years, data from the existing elements of the SuperDARN network have yielded contributions to wide-ranging topics in solar-wind—magnetosphere—ionosphere—atmosphere coupling. These have included the IMF B_y-dependence of dayside convection patterns, the identification of the dayside cusp, the observation of flow bursts in dayside convection, the identification of large-scale nightside oscillations in convection apparently associated with magnetospheric cavity modes, and the identification of sources of high-latitude atmospheric gravity waves. As the SuperDARN network evolves it is anticipated that it will yield increasingly refined data on the global extent and evolution of ionospheric irregularities, ionospheric convection, and high-latitude gravity waves. The data from the network will be of significant value to any investigation into the large-scale dynamics of solar-terrestrial coupling processes. Consequently, the SuperDARN team welcomes any inquires and/or suggestions from the satellite, ground-based and theory communities into the potential application of the network.

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SOLAR RADIO ASTRONOMY AT TREMSDORF

Fig. 1. View of the antenna site at the Observatory of Solar Radioastronomy in Tremsdorf. The radio spectrograph uses three of the parabolic mirrors (10.5 m, 7.5 m, and 4 m diameter) with crossed logarithmic-periodic feeds. Observations between 40 and 100 MHz are recorded by the double-structured, logarithmic-periodic Yagi aerial in the background right of the main building.(photo: R. Engler, public relations).

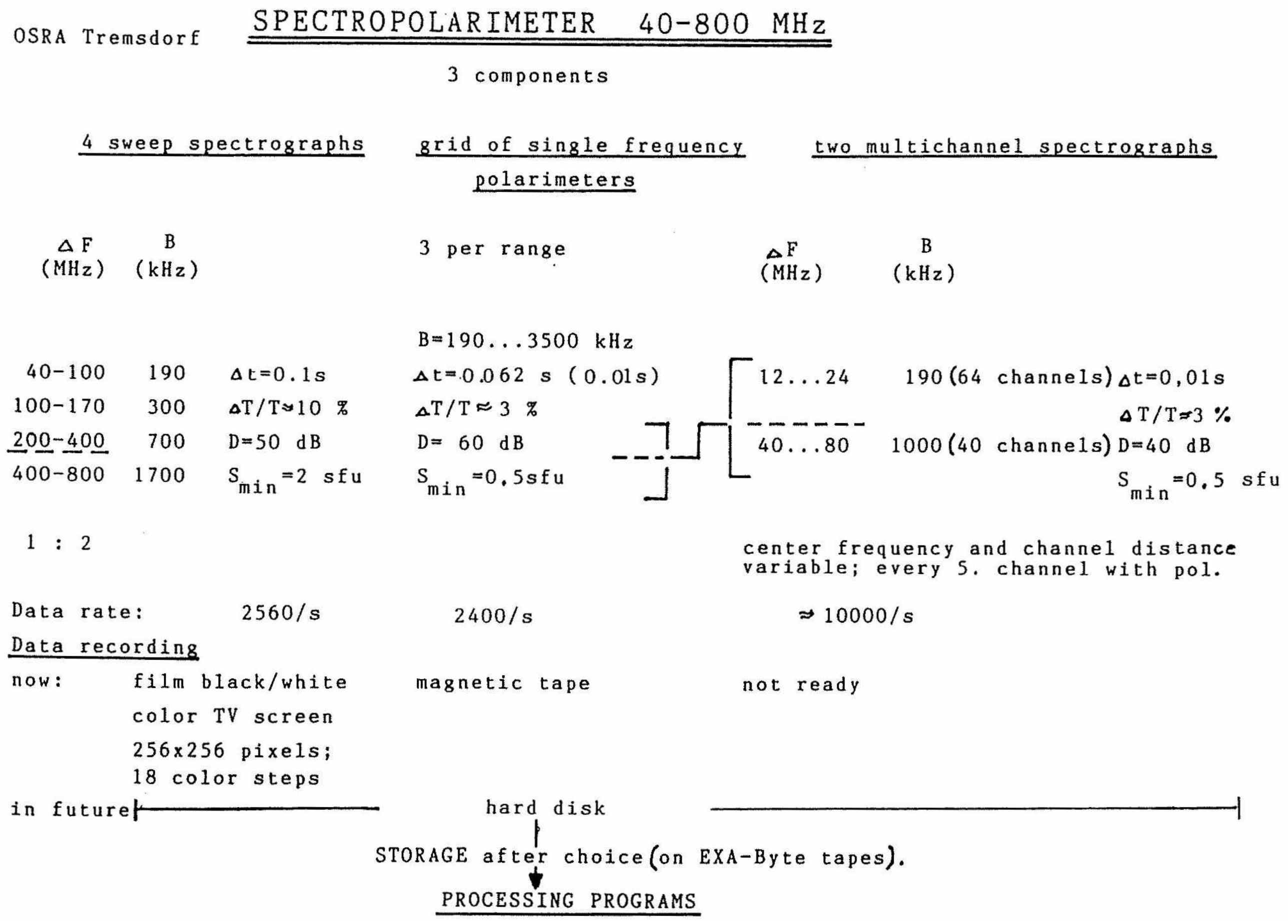
Modern radio astronomy in Germany began relatively late after World War II. In the eastern part of Germany O. Hachenberg at the "Heinrich-Hertz-Institut fur Schwingungsforschung in Berlin" and H. Daene at the "Astrophysikalisches Observatorium Potsdam" initiated the first successful efforts in solar radio astronomy. On the agreement of both institutes in June 1953, the work in the microwave region and in the meter and decameter wave region was concentrated at the "Heinrich-Hertz-Institut" in Berlin and at the "Astrophysikalisches Observatorium Potsdam", respectively. The evolution at both sites has proceeded relatively independently.

The first attempts to receive solar radio radiation trace back to the year 1896. In Potsdam J. Wilsing and J. Scheiner reported their results in the journal "Astronomische Nachrichten" [1]. Although they were unsuccessful in establishing the existence of solar radio emission, their experiments marked the birth of radio astronomy, particularly of solar radio astronomy. 58 years later, H. Daene founded — after first attempts with an 8 m dish and a 176 MHz receiver at the "Sternwarte Potsdam-Babelsberg" — the "Observatorium fur solare Radioastronomie" in Tremsdorf, about 15 km to the southeast of Potsdam and roughly 25 km south of Berlin. His intention was to record the solar occultation on June 30, 1954 in the radio wave domain. Up to now there have been excellent observing conditions. During the International Geophysical Year (1958) the Sun was observed at three frequencies (23, 113 and 234 MHz) in Tremsdorf. During the following years the polarisation of solar radio bursts was routinely monitored at several frequencies below 100 MHz for the first time. These measurements resulted in the first systematic study of the polarisation of solar type III/V radio bursts [2]. After the cessation of the observation of solar radio emission at the "Heinrich-Hertz-Institut" in Berlin in 1972, the microwave patrol receivers were transferred to Tremsdorf. From then on the Sun has been daily and routinely monitored on at least 10 frequencies in the range 23 – 9500 MHz.

At the present time, the Tremsdorf Observatory, belonging to the "Astrophysikalisches Institut Potsdam", is the only solar radioastronomical facility in Germany. The solar radio station in Weissenau (Astronomisches Institut of the University of Tubingen) located in the south of Germany was closed in 1992 after more than 25 years of continuous observations using a sweep spectrograph in the range of 100 - 1000 MHz. During the last few years a new radio spectrograph, consisting of three different instruments (cf. Table 1), was built in Tremsdorf. These are:

(i) 4 sweep spectrographs with a sweep rate of 10/s in the ranges: 40 - 100 MHz, 100 - 170 MHz, 200 - 400 MHz, and 400 - 800 MHz;

(ii) a grid of 14 single frequency polarimeters at the frequencies: 42, 64, 83, 112, 136, 164, 234, 287, 330, 380, 428, 526, 638, and 775 MHz, with a time resolution of 0.01 s and an intensity resolution of $\Delta T/T$ of 3 %, where T denotes the radiation temperature corresponding to the intensity I meas-



OSRA Tremsdorf

SPECTROPOLARIMETER 40-800 MHz

3 components

4 sweep spectrographs			grid of single frequency polarimeters	two multichannel spectrographs		
ΔF (MHz)	B (kHz)		3 per range	ΔF (MHz)	B (kHz)	
			B=190...3500 kHz			
40-100	190	Δt=0.1s	Δt=0.062 s (0.01s)	12...24	190 (64 channels)	Δt=0,01s
100-170	300	ΔT/T≈10 %	ΔT/T≈3 %			ΔT/T≈3 %
200-400	700	D=50 dB	D= 60 dB	40...80	1000 (40 channels)	D=40 dB
400-800	1700	S_{min}=2 sfu	S_{min}=0,5sfu			S_{min}=0,5 sfu
1 : 2				center frequency and channel distance variable; every 5. channel with pol.		
Data rate:		2560/s	2400/s	≈ 10000/s		

Data recording

	4 sweep spectrographs	grid of single frequency polarimeters	two multichannel spectrographs
now:	film black/white color TV screen 256x256 pixels; 18 color steps	magnetic tape	not ready
in future	hard disk	hard disk	hard disk

STORAGE after choice (on EXA-Byte tapes).

PROCESSING PROGRAMS

ured at the frequency *f*.);

(iii) two multi-channel spectrographs with bandwidths of 12 and 40 MHz which can be chosen anywhere in the range of 200 - 400 MHz and 400 - 800 MHz, respectively. This last instrument is also called a "spectrographic microscope". This design of this three component radio spectrograph enables measurements of solar radio emission with higher spectral and temporal resolution than previous radio spectrographs. A photograph of the Observatory antenna site is shown as Figure 1.

The radio emission of the Sun is generated in the corona. Since the Sun is an active star, its radio emission has a thermal and nonthermal component. The plasma in the solar corona represents a collisionless plasma dominated by magnetic forces. The coronal radio emission in the meter wave range is generally considered to be excited near the local plasma frequency. Thus, a radio source travelling upwards in the corona, and so through decreasing plasma frequencies, show a drift in the dynamic radio spectrum from high to low frequencies. High energy electron beams propagating through the corona produce fast drifting bursts in the dynamic radio spectra. If they travel along open magnetic field lines they are observed as the so-called type III bursts. In fact type III bursts are even recorded below 1 MHz by satellite, indicating that the electron beam enter interplanetary space. If the high energetic electron beam propagates in a closed magnetic field configuration, i.e., in a coronal loop, it produces a type U burst.

An example recorded by the new radio spectrograph in the range between 170 and 40 MHz is shown in Figure 2. It represents the radio signature of an electron beam propagating with a speed of 50,000 km/s = 0.17c in a coronal loop. The turning point at 50 MHz indicates the top of the loop located at approximately 630,000 km above the photosphere.

The coronograph LASCO aboard the ESA/NASA satellite SOHO (scheduled for late 1995) will observe the corona from 1.1 to 30.0 solar radii [4] (cf. Fig. 3). According to a special density model of the solar corona [3] the new radio spectrograph in Tremsdorf can monitor coronal radio radiation up to 2 solar radii (cf. Fig. 3). The LASCO coronograph C1 [4] and the radio spectrograph of the Tremsdorf observatory will observe the same height region of the corona as indicated in Fig. 3. The non-thermal solar radio radiation is generated by supra-thermal electrons so a solar radio spectrograph is a sensitive detector of high energy electrons in the corona. Since the new radio spectrograph in Tremsdorf sensitively detects high energetic electrons and monitors plasma physical processes in the corona with a very high time resolution, it will contribute to the SOHO mission by ground based observations.

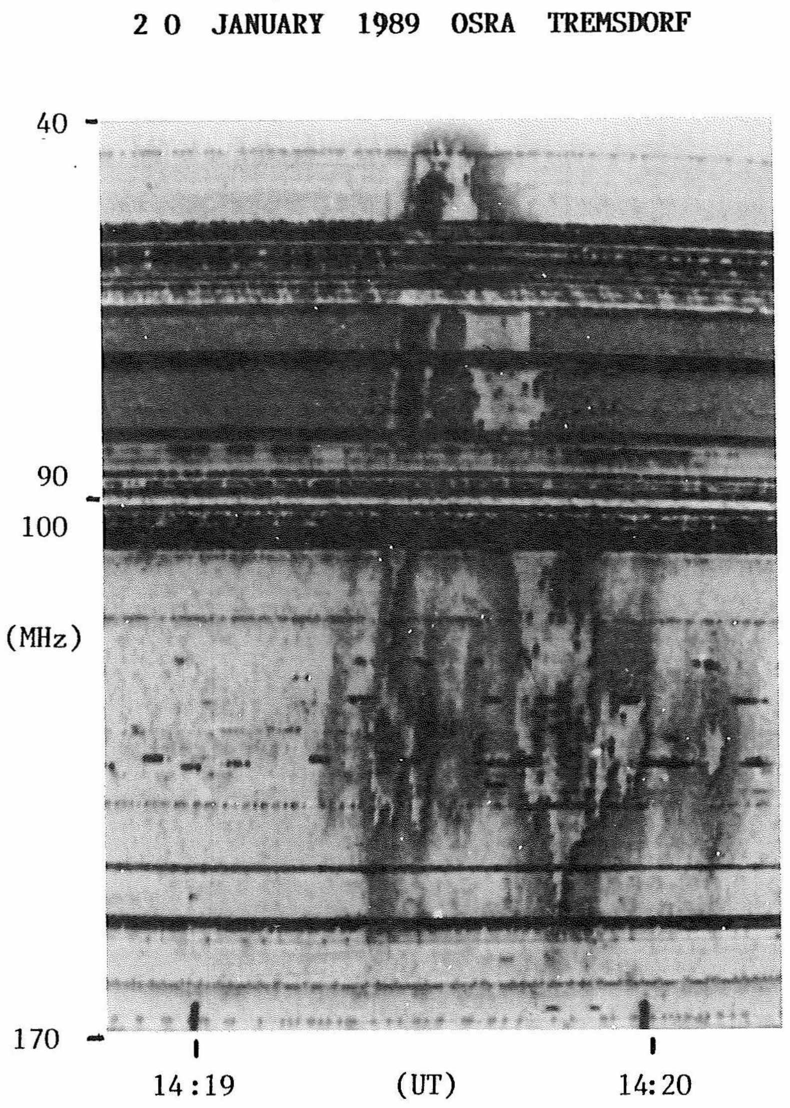


Fig. 2. Spectrogram of a solar type U burst starting at 14:19:23 UT. In the original the intensities are colour coded.

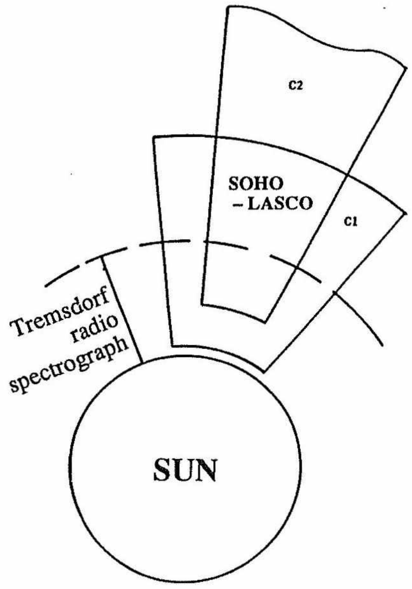


Fig. 3. The radio spectrograph in Tremsdorf is able to receive the solar radio radiation up to an height of 2 solar radii, approximately. The coronographs LASCO (C1, C2, and C3) aboard the SOHO satellite will cover the corona from 1.1 up to 30.0 solar radii [4]. In particular, the radio spectrograph in Tremsdorf and the C1 spectrograph will observe the same height region of the corona. Both data sets are highly significant to study such problems as the onset of coronal mass ejections and their connection to the flare process.

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RADIO SCIENCE

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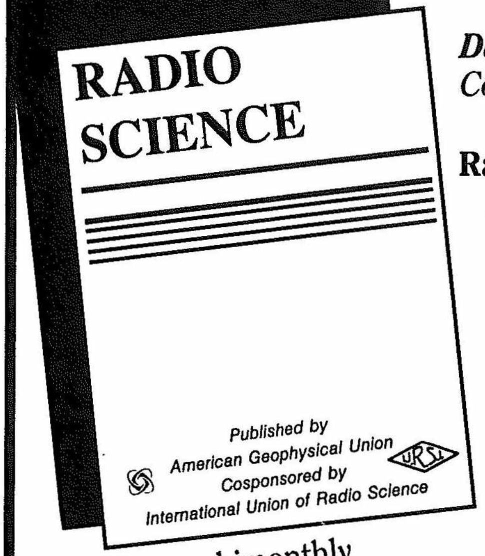
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B.V. KRISHNA MURTHY, K. PARAMESWARAN, K.O. ROSE & M. SATYANARAYANA (India), Temperature dependences of stratospheric aerosol extinction at a tropical station.

V.I. FOMICHEV, A.A. KUTEPOV, R.A. AKMAEV & G.M. SCHVED (Russia), Parameterization of the 15 μmCO_2 band cooling in the middle atmosphere (15-115 km).

R. FURRER, W. DÖHLER, H.-J. KIRSCH, P. PLESSING & U. GÖRSDORF (Germany), Evidence for vertical ozone redistribution since 1967.

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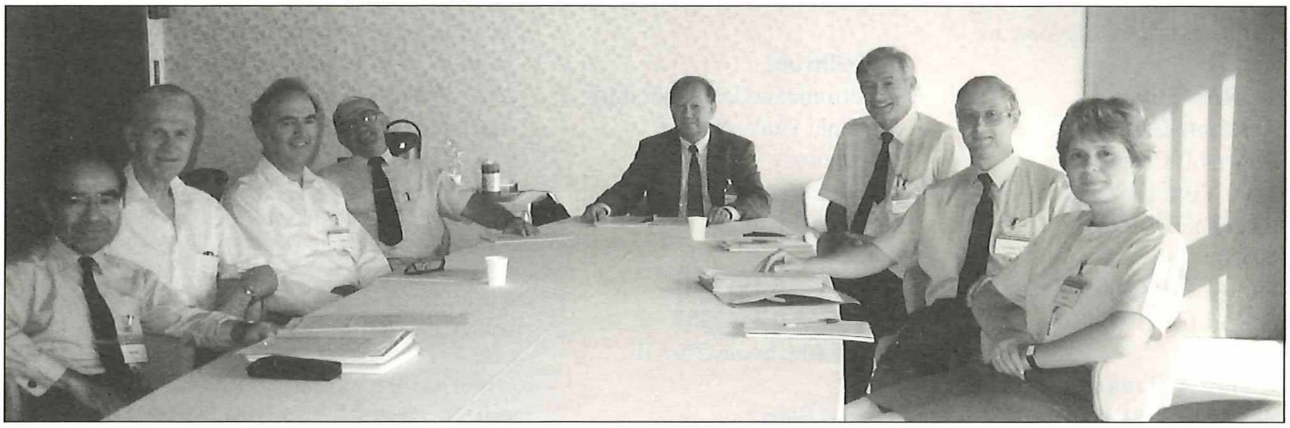
The Radioscientist

The magazine of URSI
ISSN 1170-5833

Editor: R. L. Dowden
Vol 4 N° 3
September, 1993



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The Radioscientist

The Radioscientist is published quarterly by
Radio Science Press Avenue Circulaire 3
Brussels, B-1180, Belgium
and issued on **1st March, June, September and December.**

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COVER: The new Board of Officers elected at Kyoto. Left to right: *Vice Presidents*, T. Okoshi, T. B. A. Senior, J. B. Andersen, and P. J. B. Clarricoats; *President* P. Bauer, *Past President* E. V. Jull, *Secretary General* P. Lagasse, *Administrative Secretary* I. Heleu.

URSI and the New World Order

We seem to be at a watershed in human history with a crumbling, or collapse, of old orders and an emergence of new. There are profound changes not only in political and economic structures but also in the structure of the science and technology which helped precipitate the changes. Certainly the physical sciences, and particularly radio science, flourished under government support during the decades of cold war competition. Just as surely radio science has vastly improved telecommunications and the rapid spread of information resulting in a weakening of government information control and a raising of public expectations. This process continues globally, creating difficulties for governments almost everywhere. While the early radio scientists who sowed these seeds of change may not be experiencing the fruits of their endeavour now, their successors surely are.

Our enormous relief at the dismantling of the deadly confrontation of the cold war era is accompanied by disruption and uncertainty in the careers of many of our colleagues. These are mainly in the research institutes of East Europe and the former Soviet Union and some research and development companies in the western nations. Here is massive array of intellectual skills for scientific and economic benefit which should not be allowed to languish, but harnessing them will require time and especially economic growth and international cooperation. URSI has a vital role here for it was founded to further international cooperation in the radio sciences.

Indeed URSI was one of the first international scientific unions (1919) because the need for international cooperation existed from the beginnings of radio science. It has had a long and famous history, from early achievements in radio broadcasting to the spectacular discovery and exploitation of the ionosphere beginning in the 1920s. It survived very well the economic and political calamities of the 1930s and 1940s and emerged from the dark interlude of the war, during which it was unable to function, more active and broader in scope than before. It went on to help usher in a brilliant period of space research, first proposing instrumented satellites in 1954 and the International Geophysical Year (1957/58) which now has a successor in the IGBP. Its frequency range expanded to from ELF to optics and its spatial domain from the depths of the earth to the most distant reaches of the universe. Recently it has been extended to biological matter also. Who could have foreseen today's URSI 50 years ago and who would dare to predict the future URSI today?

This much is clear. The possibilities for and potential benefits of international cooperation in radio science probably have never been greater. Emerging from the collapse of the old order there appears to be an economically competitive but more globally cooperative society, which more than ever will require the radio sciences to function. Quite apart from other motivating factors, the competitive enthusiasm of the newly industrialised countries of Asia for new uses of radio sciences should encourage the pursuit of new discoveries. So also should the example of the remarkable scientific and industrial successes in telecommunications of Japan, our host country for this 24th General Assembly. Centres of activity in the radio sciences may shift geographically but the scale of activity is almost certain to increase. Progress in radio science will continue most efficiently if the traditions of URSI, that is international cooperation and the free circulation of scientists, are maintained. We must ensure that they are.

E V Jull

Editor's Column

The Editor's Page, which was usually a page and a half, is now a Column. This column, which may spread onto columns further on in later issues, will be about the logistics and mechanics of the issue, leaving the comment function to invited guest editors as here.

For those of you who participated at the 24th General Assembly of URSI at Kyoto, this issue is a repeat of the special one issued at Kyoto, apart from the cover photo added and a few typos removed. Those of you who were not at Kyoto, who presently receive *the Radioscientist* and *the Bulletin* by subscription you paid yourself, and who want to get the new *Radioscientist-Bulletin*, **may** need to take out a subscription. But first check with your local URSI Member Committee (what used to be called your "National Committee") in case you are to be placed on the free list. In either case, any radio scientist/engineer who gets the *Radioscientist-Bulletin* directly and individually addressed from Belgium (URSI HQ) is an individual member of URSI's network of correspondents and will receive a membership card and number as evidence therof for the purposes of special discounts. Thus you are entitled to discounted subscription rates for *RADIO SCIENCE* and the *Journal of Atmospheric and Terrestrial Physics (JATP)*, both of which now have URSI sponsorship and carry the URSI logo. The *JATP* subscription rates for URSI members is a mere 10% of the library rate, but such a subscription must be only for one's personal use. Library cancellations of either journal traced to abuse of these discount privileges would jeopardise these arrangements. Be fair! For further details, see the advertisements for these journals later in this issue.

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Introduction

It has long been known [1] that whistler amplification in the magnetosphere produces precipitation into the ionospheric D-region of energetic (> 40 keV) electrons from the Radiation Belts. Since whistlers are dispersed lightning impulses, this is called lightning-induced electron precipitation (LEP). Each energetic electron can produce thousands of electron-ion pairs, and so the LEP produces a lightning-induced ionisation enhancement (LIE). The lateral dimensions of a LIE may represent the D-region footprint or down-mapping of the guiding whistler duct, and are usually assumed to be of the order of 100 km.

In the Earth-ionosphere waveguide, the LIE appears to a horizontally travelling VLF wave as an anomaly within which the complex propagation vector **k** is perturbed by Δ**k**. As a result, the VLF wave is diffracted horizontally (this two-dimensional model is adequate for our purposes) in a pattern determined by the lateral dimensions and ionisation distribution of the LIE. At large distances "down wave" of the LIE (i.e. in the far field of the re-radiating LIE) the diffraction pattern is essentially the Fourier transform of the LIE and so the lateral dimensions of the LIE and the width of the far field diffraction pattern are inversely related.

LEP occurs ~1s after the lightning which induced it, corresponding to the whistler and electron travel times. The LEP duration ranges from a few tenths to a few seconds (e.g. due to whistler triggered emissions, multi hop whistlers, backscattered electrons, etc.). The LIE intensity variation in time is largely the integral of the LEP intensity, reaching maximum at about the end of LEP and then decaying exponentially with a time constant of about 30 seconds.

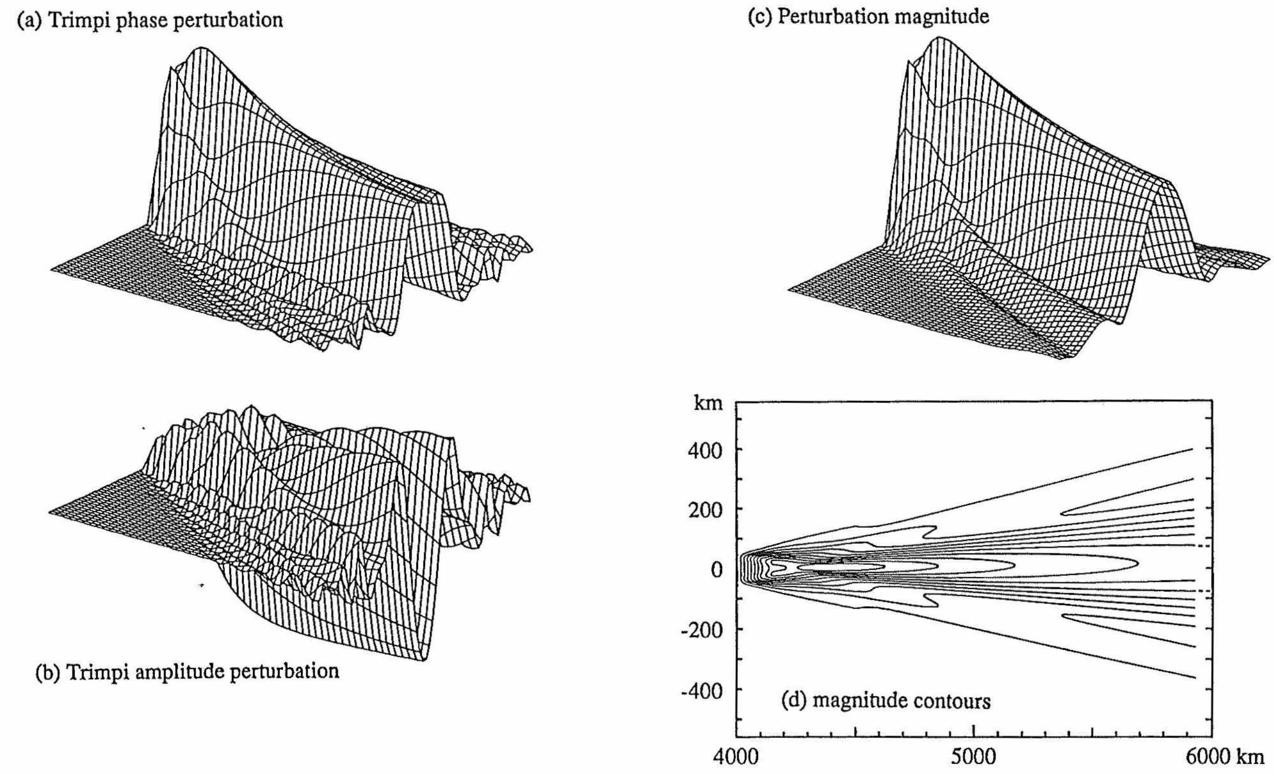
A very recent discovery, as yet unpublished, is that another form of lightning-induced ionisation enhancement (LIE) is produced coincident with the lightning (i. e., without delay) but which decays in a much shorter time (~ 1 second) implying that it is formed at much lower altitudes than the LEP produced LIE. This rapid onset, rapid decay (RORD) LIE is often produced by the same lightning as is LEP produced LIE. If both types of LIE occur in the same location (or merely in the same Fresnel lane [2]) this would appear as the "early' or "fast" Trimpi first described by Armstrong [3].

A VLF receiver placed down wave of the LIE (whether LEP produced or RORD LIE) will see the wave from a phase-stable transmitter as perturbed in amplitude [1] and in phase [4] depending on the receiver position within the diffraction pattern [2]. If the transmitter, LIE and receiver are in line (same great circle) then the phase perturbation is positive (phase advance) and the amplitude perturbation is negative (amplitude reduction). The relative sizes of these two perturbations depends on the altitude distribution of the LIE [5] but not so much as to change the signs of the phase and amplitude perturbations. If the receiver is laterally displaced from the transmitter-LIE great circle, the perturbation signs change progressively and cyclically with increasing lateral displacement in the order: +, – (phase and amplitude, respectively, at zero receiver displacement); +, +; –+; –, –; +, – (again, after completing one cycle); and so on. The first repeat of positive phase, negative amplitude perturbation (+,–) occurs when the transmitter – LIE – receiver distance is one wavelength longer than the transmitter – receiver distance (direct path).

A sufficiently long and dense array of VLF receivers arranged transverse to the transmitter–LIE line would see all these perturbation combinations provided the diffraction pattern of the LIE is wide enough. This width depends on both the lateral size and the lateral ionisation distribution of the LIE — a Gaussian distribution giving the least diffraction spread. In fact, if the details of the diffraction pattern are adequately measured by such an array of receivers, the shape (lateral variation in ionisation enhancement) and position of the LIE can be determined by the VLF equivalent of holography [2].

Each VLF receiver measures both the amplitude and phase perturbation of the subionospheric transmission from one or more VLF transmitters (most of our research uses the single transmitter, NWC, situated nearly 6,000 km west of our array in N.Z., and which radiates 1 MW at its current frequency of 19.8 kHz). Even the relatively slow (~1 s) onset of "Trimpi" perturbations is quite adequate for precise measurement of the amplitude and phase (relative to an arbitrary but stable standard) of the unperturbed transmission. By phasor subtraction of this unperturbed transmission from the perturbed one, we can determine the phase and amplitude of the wave scattered by the LIE. This concept (scattering or diffraction) is also valid if the transmitter, LIE and receiver are in line (same great circle). When the LIE is also laterally extensive this diffraction approach gives the same answers as the "geometric" approach which considers only propagation along the transmitter–LIE –receiver great circle path.

The converse, however, is not true. Figure 1 shows the amplitude and phase perturbation expected from a square LIE corresponding to a uniform ionospheric depression over a 100 x 100 km area, aligned NS and EW, from a VLF transmitter placed 4000 km due west of the western edge of the LIE. This means that the wave phase velocity in the Earth-ionosphere waveguide is constant within this rectangular region (100 km E-W by 100 km N-S) but is slightly higher (due to the depression of the effective height of reflection) than that outside this region. A receiver placed anywhere in the horizontal area covered by these mesh plots would experience the perturbation indicated by the vertical displacement of the mesh. Note that the perturbation shadow or downwave "wake" is much wider than the geometric shadow which would apply for vanishing small wavelengths. The width of such a geometric shadow is indicated by the short dashed lines at the right hand end of the contour plot


(a) Trimpi phase perturbation

(c) Perturbation magnitude

(b) Trimpi amplitude perturbation

(d) magnitude contours

Fig. 1. Perturbation "shadow" (or "wake") cast by a square LIE corresponding to a uniform ionospheric depression over a 100 x 100 km area, aligned NS and EW, from a VLF transmitter placed 4000 km due west of the western edge of the LIE. The shadow is calculated out to 6000 km beyond this edge in the direction of the unperturbed waves (eastward) and about ± 500 km laterally (NS). The mesh plots are viewed from the south west. The vertical dimension of these is (a) the Trimpi phase perturbation in deciradians, (b) the percentage amplitude perturbation and (c) the perturbation "magnitude" which is approximately (for small perturbations) proportional to the square root of the sum of the squares of the phase and amplitude perturbations. This magnitude is also contour plotted in (d) to show the perturbation immediately under the ionospheric depression (first 100 km of the shadow). The dashed lines at the extreme right of (d) indicate the edges of a purely geometric shadow.

(Figure 1 d). Within such a geometric shadow the perturbation would a uniform one of phase advance and essentially no amplitude variation. In the real situation of VLF waves, Figure 1 (a) and (b) shows that both amplitude and phase perturbation is produced even though the ionospheric depression produces only an increase in phase velocity. Note also that receiver sites of maximum phase perturbation are those of zero amplitude perturbation and *vice versa*. Such strange behaviour to one thinking in terms of geometric optics is easily understood as the phasor addition of the unperturbed and scattered waves.

Figure 1(c) shows the magnitude of the signal scattered by the square LIE. This could be regarded as the "diffraction shadow" of the block. The cross section of the shadow at any range from the LIE represents the diffraction pattern. If, on the other hand, the LIE is circular and if the radial distribution of the ionisation enhancement (and so the amount of propagation perturbation) is Gaussian, the cross section of the diffraction shadow at all ranges is Gaussian. Antenna engineers will recognise this as the equivalent of a broadside array having a tapered (Gaussian) feed to suppress sidelobes while the rectangular block LIE corresponds to a uniformly fed array. Theorists frequently use this Gauusian LIE model [5, 6] because it looks "natural" and because of its convenient transform properties, but these very properties of minimum diffraction spread and fine structure set it apart as an extreme not necessarily met in real LIEs.

So far, our VLF antenna array has consisted of only five elements arranged broadside (north-south) to the transmission from NWC (approximately west to east). Each element consists of antenna, preamplifier and receiver. The unperturbed signal from NWC provides the phase reference for each of these so in that sense the array is coherent. Four or the elements span only 50 km and are spaced in multiples of $3\lambda/4$ so that the phase of the LIE–scattered signal, relative to the unperturbed phase of NWC, can be compared from element to element without ambiguity (folding over 2π). If the LIE is in the same direction as NWC the scatter phase is the same at each element. If the LIE–scattered signal comes from a different direction, the resulting linear variation of scatter phase along the array enables the direction of arrival to be determined. The fifth element is nearly 600 km further away, too far for scatter phase measurement but useful as an indication of the width of the diffraction pattern.

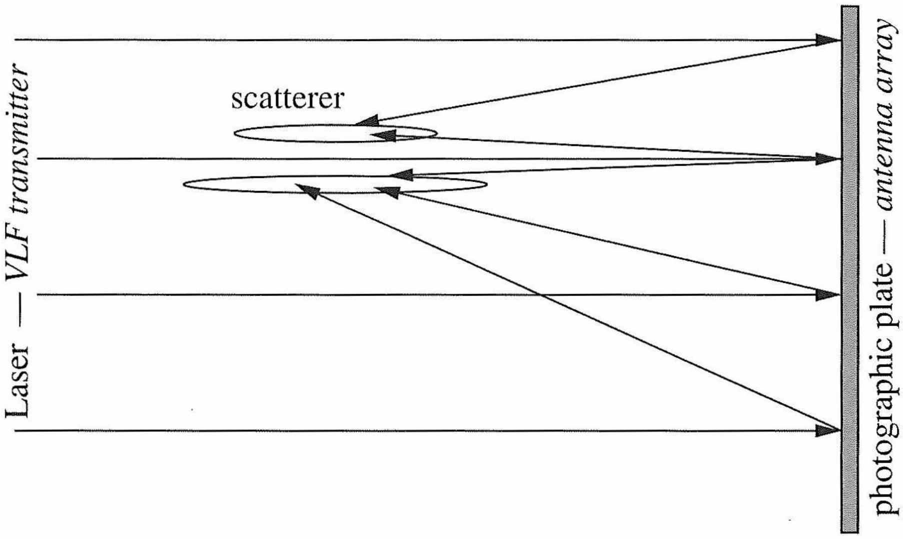


Fig. 2. VLF holographic reconstruction based on that of its optical counterpart. The optical items are labelled in ordinary type while the VLF counterparts are labelled in italics. During VLF "exposure" both phase and amplitude perturbation is recorded while in the optical case only the amplitude perturbation is recorded. For reconstruction, the phase standard (the laser in the optical case) is not required in the VLF case.

Data from this limited array lead to the identification of the rapid onset, rapid decay (RORD) perturbation which might otherwise have been dismissed as a broadband sferic instead of a very short duration (~1 s) echo of the NWC signal. Apart from our verification of the echo nature of the RORD perturbation, our conclusions [7] from the use of the present array refer only to the conventional "Trimpi" perturbations produced by LEP LIEs. For these we find that the diffraction pattern is frequently wider than 600 km though the centre is usually near or even north (equatorward) of the northern end of the array. Directions of arrival measured on the four elements at the southern end are usually north of the direction of NWC, which also indicates that LIEs occur typically at lower latitudes than Dunedin (~45° S). Although the number of elements is inadequate to determine the shape of the diffraction pattern, two things are clear. Firstly, Gaussian LIEs sufficiently compact to produce the wide diffraction patterns would not be strong enough scatterers to produce the perturbation magnitudes observed. Secondly, deep nulls sometimes occur in the diffraction pattern implying sidelobes like those in Figure 1 which are clearly inconsistent with Gaussian LIEs. Such nulls are only observable if they fortuitously occur on one of the three middle elements, so such non-Gaussian LIEs are probably common.

Our guess is that LIEs are the footprints of whistler ducts, sometimes of two or more ducts simultaneously. Such ducts would be arrayed in latitude (north-south) but probably elongated east-west. Such a "venetian blind" array of LIEs would produce pronounced grating-like diffraction effects for east-west propagation but relatively little for north-south propagation.

VLF Holography

To get an adequate VLF holographic image of the electron precipitation pattern, we need a longer array and many more elements. We are presently building a 30–element broadside array spanning some 500 to 1000 km along the length of New Zealand with outlying individual elements in Australia. The VLF receivers are digital and software intensive, and fit on a standard sized board for running in a low end personal computer (PC). From previous experience, amateur radio operators ("hams") are happy to participate in such experiments and can often provide their own PCs. The cost of such an array is almost proportional to the number of elements but almost independent of the element spacing and so the total length of the array. As we will see below, increasing the spacing increases the resolution but also increases the spurious responses.

The principle of VLF holographic reconstruction is basically that of its optical counterpart as depicted in Figure 2. The optical items are labelled in ordinary type while the VLF counterparts are labelled in italics. There are some important differences, however. In the optical case, the 3-D holographic image is produced from the 2-D interference pattern on the photographic plate. In the VLF case, the 1-D pattern of amplitude and phase sampled by the array produces only a 2-D (geographic) image. In the optical case, the dimensions of the photographic plate are some 200,000 wavelengths compared with some 30 to 100 in the VLF case.

For the first two simulations to be shown, a uniform array of 31 equally weighted, equispaced elements is used. The amplitude and phase of the signal scattered from a point scatterer is calculated for each element in the array. This produces a diffraction pattern sampled by the array and so the 1-D hologram we need to reconstruct the scatterer (a point one, in this case) For this reconstruction the roles of the 31 elements are reversed, meaning that each one is notionally supposed to radiate a VLF wave of the phase and amplitude

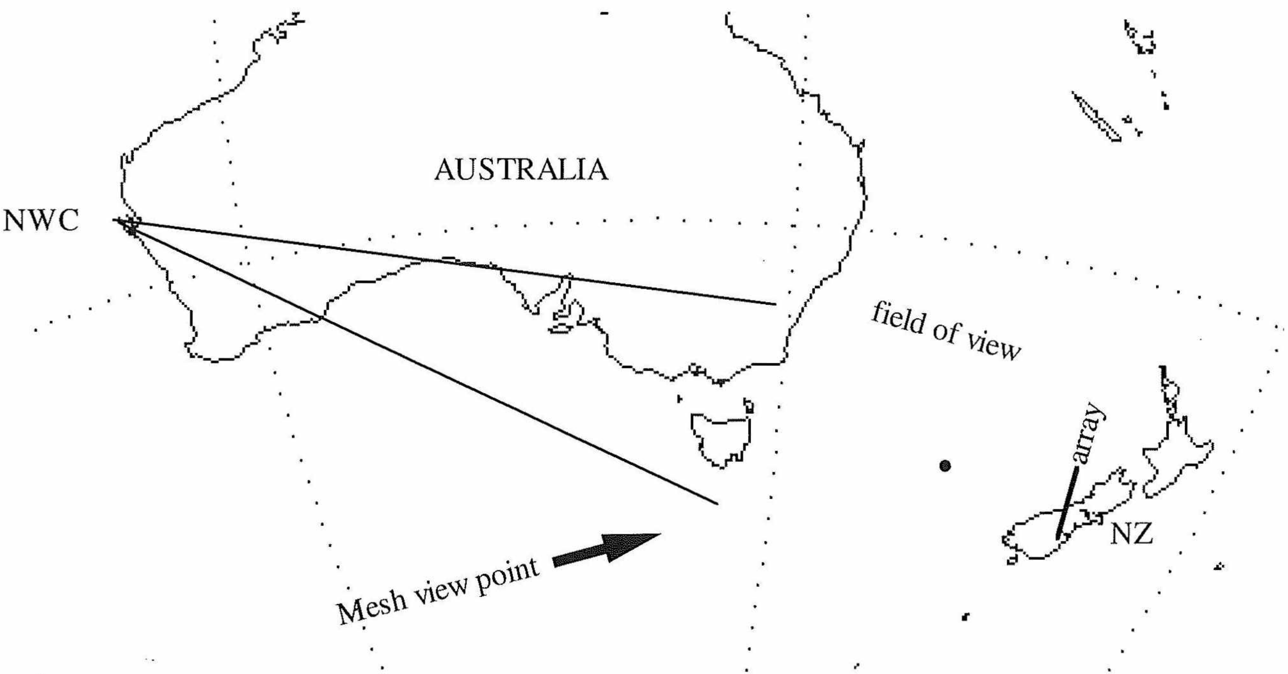


Fig. 3. The field of view (1800 x 1200 km) of the VLF holograph shown in the mesh plot reconstructions (e.g., Figure 4 below) is shown above as the gray rectangle. The thick arrow shows the viewing direction of the mesh plots below. The point scatterer is the circular spot 600 km from the eastern edge. The VLF antenna array (thick line over NZ) is the 450 km one appropriate for Figure 5. For the other two mesh plots the array length is three times this length. In practice, the array would be arranged along the axis of New Zealand and the elements would be sited conveniently and so not exactly broadside or linear or evenly spaced.

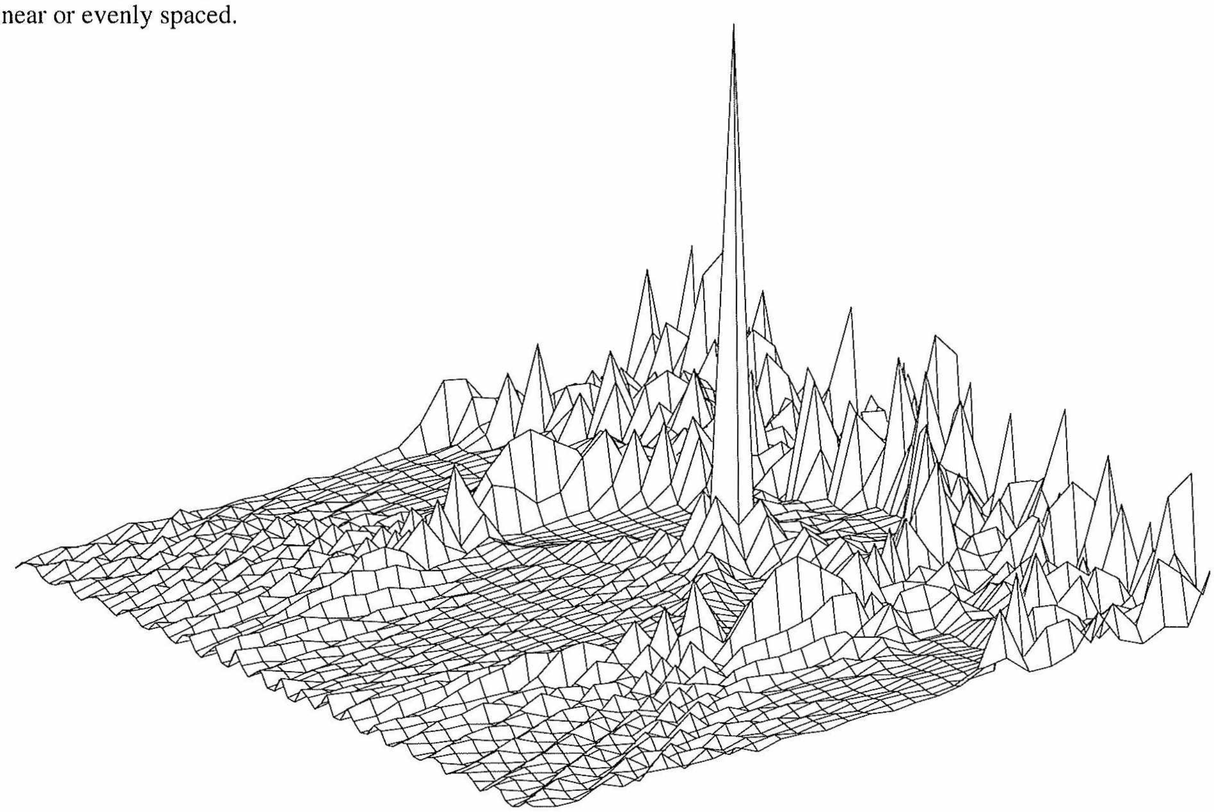


Fig. 4. Mesh plot of the wave field power deduced in 2-D holographic reconstruction from the 1-D diffraction pattern along the array. Power is the vertical dimension. The horizontal dimensions span the field of view shown in Figure 3 above. In this case, there are 31 elements spaced 3λ (45 km) apart to produce a total array length of 1350 km. Note the "grass" due to spurious responses. The "east-west" scale differs from the "north-south" (broadside to NWC), so the east-west resolution is worse than it might appear here.

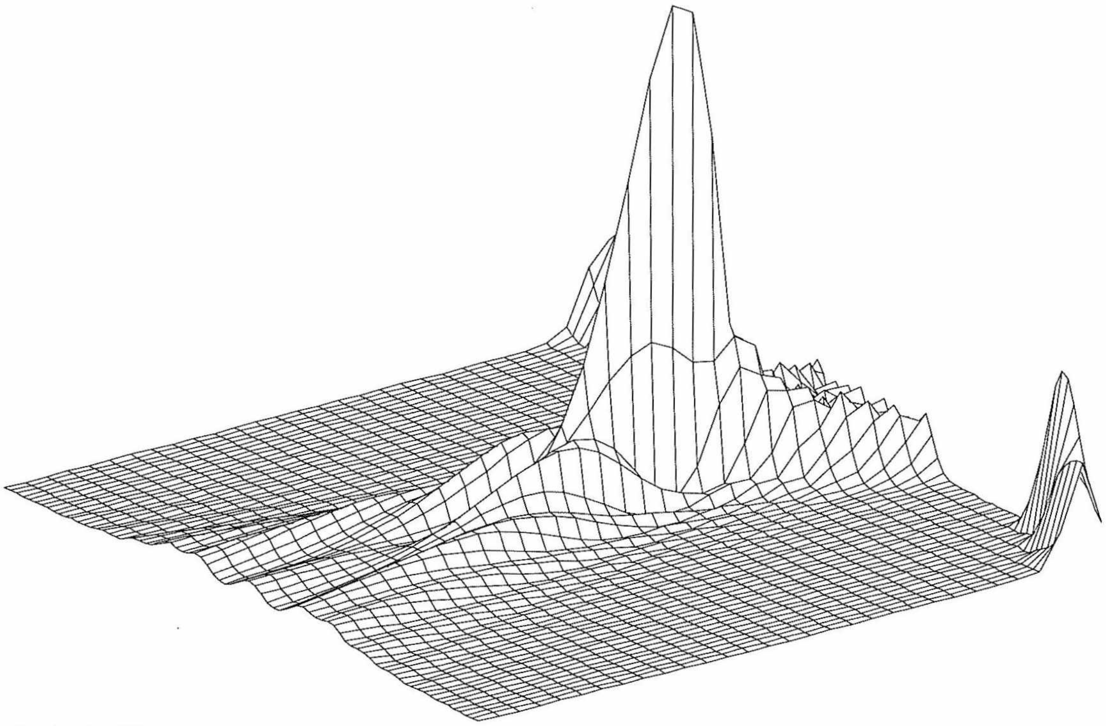


Fig. 5. As for Figure 4 except that the element spacing is 1λ (15 km) so that the array length is 450 km.

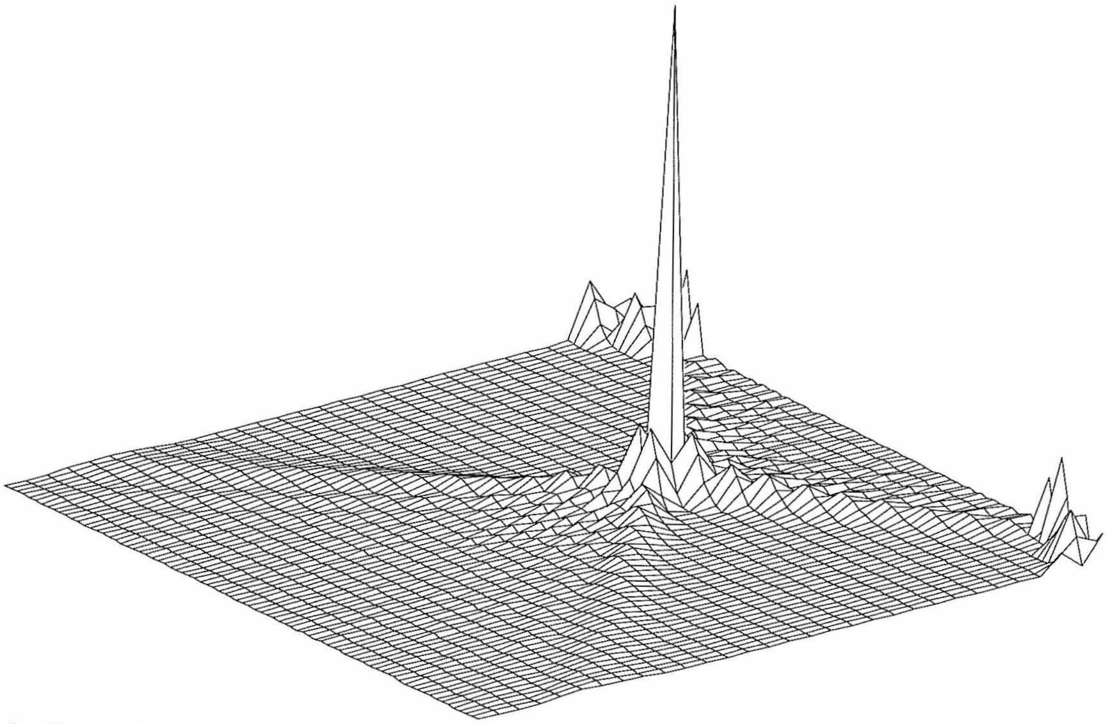


Fig. 6. As for Figures 4 and 5 but using 93 elements spaced 3l (45 km) apart to maintain the array length of 1350 km. This gives high resolution without the "grass" but would cost three times as much.

of the scattered wave it "actually" (but previously calculated in this simulation) received. The mesh plots in Figures 4 and 5 are of the resultant wavefield power obtained by summing the phasor field contributions from the 31 elements. The position of the VLF transmitter is that of NWC (19.8 kHz) as seen from New Zealand and is 3745 km west of the left hand edge. The field of view in these is shown in Figure 3 as the gray rectangle. The borders of the field of view are not strictly aligned to longitude and latitude because NWC is somewhat north of west. This field of view which corresponds approximately with the Tasman Sea between New Zealand and Australia is a common location for LIEs during the austral winter as determined from our 5-element array (during the summer, LIEs are more common over north western Australia).

The position of the point scatterer (black circle in Figure 3) is more closely determined in azimuth (mainly latitude in this case) than in range (mainly longitude here). This is because the azimuthal position or direction of arrival at the array depends on the linear variation of the received phase along the array, or slope of the wave front relative to the array line, while the range from the array depends on the second derivative of the phase along the array, corresponding to the wavefront curvature. If the scatterer is much further from the array (several times the array length) the azimuthal determination of a point scatterer, or the azimuthal distribution of an extended and structured scatterer (e. g., the footprints of multiple whistler ducts) is well determined while the range information is largely lost.

In an attempt to regain the range resolution the elements are spaced by 3λ (about 45 km) for the simulation calculated for Figure 4. For such an array of length 1350 km (90λ), the range at which the far field becomes dominant is about the circumference of the Earth and so well beyond the transmitter! For the much shorter ranges in the field of view shown, the near field dominates. The array diluteness gives rise to an unacceptable level of spurious responses or "grass" although the point scatterer (largest spike near the centre of the field of view) is well resolved. For Figure 5 the element spacing is reduced to 1λ (15 km). This removes the grass-like spurious responses of Figure 4 but the longitudinal (east-west) resolution is very poor, and even worse than it might appear because the east-west span of the field of view is 50% larger than the north-south span. There are high angle or sidelobes in the top and bottom corners of the field of view, but these could be removed by low pass filtering the diffraction pattern in amplitude and phase as sampled by the array elements. Since all such processing is done off line, several forms of processing can be used for any event. For three times the cost (93 elements) we could have both the high resolution (1350 km array length) and a low level of grass (15 km spacing of elements) as shown in Figure 6. In practice, the array would have to lie along New Zealand to fit it on land, but this would have little effect on the resolution.

Applications

Although the incentive for developing this holographic technique was for the location and imaging of lightning-induced electron precipitation, our VLF array can be used for locating regions in which the VLF propagation velocity and/or attenuation is changing by whatever cause, provided the change is measurable. If the change and return to normal is fast, as is the case for RORDs, quite small changes are measurable. The time scales (onset and decay) for classic Trimpis are longer by an order of magnitude which means that larger changes are needed for measurement. To some extent, a very slowly formed propagation anomaly could be detected and located by the *spatial* rate of change of VLF phase and amplitude along an array or on a moving platform [9]. Anomalies thought to be earthquake precursors (see page 72, this issue) appear to be of this form. Getting both spacial and temporal relationships with earthquakes would greatly enhance the validity of this type of precursor.

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HF Communications – Science and Technology

by John M Goodman. Van Nostrand Reinhold, 1992. ISBN 0-442-0015-2 632 pp, $74.95.

At last we have an "encyclopedic" treatment of the theory and practice of HF Communications by one of its long-time practitioners, Dr John Goodman of the US Naval Research Laboratory (NRL) in Washington, DC — one of the US Navy's foremost Labs. Although the author's perspective comes from the military milieu, most of this book can be read profitably by anyone seriously interested in HF communication. It comes close to telling us "everything we ever wanted to know" about the subject. It is a well-organised, very readable book written in a lively, absorbing, fascinating style, and the typography, figures and tables are excellent.

The preface is especially valuable to those who wonder why and how HF Communication should be used — the author does a good job delineating the "myth vs the realities" of HF. Each chapter is also succinctly summarised for the reader. Many readers skip the preface of a book, but this preface is meant to be read — those who make the decisions on research and use of HF radio should *especially* read this preface!

The first chapter starts with a concise seven page historical account of HF radio development and ionospheric studies. In this section, Goodman describes the "interweaving" of the disciplines of geomagnetism, solar and auroral observations, Maxwell's theoretical studies, Hertz and Popov's experiments, and Marconi's demonstrations of the propagation of radio waves via the "Kennelly-Heaviside" layer.

The experiments of Appleton-Barnett and Breit-Tuve, the Appleton-Hartree magnetoionic equations and the remarkable advances in theory and techniques for studying the ionosphere from 1925 until 1940 are also covered. The remainder of Chapter 1 covers the "current utilisation of HF", propagation modes, "trials and tribulations of HF" and some solutions to the problems. The section on OTH systems uses the term, "splashback" — a very colourful term for ionospheric backscatter.

Chapter 2 gives a remarkably complete overview of the "Solar-Terrestrial Environment"; from the centre of the Sun, through interplanetary space, into the earth's magnetosphere and ionosphere. Long and short-term solar activity and the effects upon the ionosphere — as well as an outline of the present prediction services is also covered. The References and Bibliography for this chapter are complete enough for the topic of the book. As in all books, there are a few "typos", such as the misspelling of Gillmor's name in the bibliography on page 31.

"The Ionosphere and its Characteristics" is the title of Chapter 3 in which the author describes ionosphere formation, properties, regions, anomalies, solar influence and ionospheric storm behaviour. The section describing the four ionospheric current systems is especially succinct, but the subsection on the high-latitude current system, neglects the work done on this topic since 1972 — i.e. that an essential component of the auroral electrojet is the increased E-region conductivity caused by auroral particle precipitation, as pointed out most recently by Kamide (1990). Also, Figure 3-23 on page 133 portrays the oval incorrectly in the western north American and Siberian sectors. Ionospheric models are discussed adequately in Section 3.8 (12 pages) and predictions are discussed briefly.

Chapter 4 (the longest, at 132 pages) covers "HF Propagation and Channel Characterisation" in exquisite detail. Topics included are: field strength, power density, polarisation, attenuation, reflection, refraction, diffraction, fading, scattering, dispersion, Doppler shift and spread, and group path delay. The section on groundwave (surface wave) propagation (4.4.2), including propagation over irregular terrain, is especially good. There is a short but reasonably complete exposition (Section 4.5) on the Appleton-Hartree equations and "sky-wave" propagation. There is an error in equation 4.5b on p.201 — a large "left-bracket" is missing in the denominator of the equation, and this reviewer wishes that the author would have used SI units throughout! A good discussion of radiowave polarisation and Faraday rotation is given in Section 4.5.1.

A short section (4.6) on "Near-Vertical-Incidence-Skywave (NVIS)" propagation mode is included, and although this mode is primarily used by the military, there are some civilian applications. This mode is primarily used when there is very thick vegetation or a hill between the transmitter and receiver — thus precluding conventional VHF through microwave line-of-sight communication. An extensive list of references is included at the end of the chapter.

The remainder of Chapter 4 is devoted to oblique-incidence skywave propagation which is, of course, the dominant HF propagation mode. The first four pages of this section gives a rather complete listing of the definition of terms used by communicators at HF, the relation between vertical and oblique propagation, ray tracing through the ionosphere, multipath and fading, channel modelling and simulators. Mitigation of the effects of HF multipath propagation various diversity techniques is a valuable section for HF communicators.

Chapter 5 describes "Performance Prediction Methodologies", generally defined by the author as "hindcasting, nowcasting, (short-term) forecasting and (long-term) predictions". The reader is provided with a general summary of the attributes of major models, a section on small computer programs and on-going efforts for improvement in long-term predictions, concluding with comments on international cooperation.

Chapter 6 is the second longest chapter in the book and deals with "Real-time channel evaluation (RTCE)", sometimes called "nowcasting". Specific RTCE classes include; oblique-incidence sounding (OIS), channel evaluation and calling (CHEC), vertical-incidence sounding (VIS), backscatter sounding (BSS), frequency monitoring (FMON), pilot-tone sounding (PTS), and error counting systems (ECS). Each of the foregoing RTCE classes are discussed in considerable detail.

Methods of solving some HF propagation problems are given in Chapter 7 on "Adaptive HF and the Emerging Technologies". The author points out that although "Adaptive HF" has been discussed for several decades, it was not until the technological advances starting in the 1970's, that actual systems were studied, culminating in the 1980's with actual system implementation. The complexity of "adaptive HF" is emphasised by the fact that the author uses 9 pages (Section 7.5) to properly *define* the subject! For instance, Goodman specifies 4 types of adaptability; transmission, link, network and system — most of this discussion, however pertains to military applications. An "encompassing definition" of "HF adaptable systems" is given by the author as, "any HF communications system that has the ability to sense its communications environment, and, if required, to automatically adjust operations to improve communications performance."

Chapter 7 includes 44 pages (Section 7.6) on "Technology: Foundation of Advanced/Adaptive HF", in which the author presents the results of the numerous technological advances made since the early 1980's, and their special applications to HF systems. Specific areas where significant advances in technology have been made are in: solid-state power amplifiers, receiver and transceiver design, antennas and couplers and modulation techniques. He concludes Chapter 7 with a good "Sampling" of adaptive systems in use (Section 7.7) and "Strategic" (military) HF adaptive systems (Section 7.8) and a 10 page reference list.

In the "Epilogue", the author briefly summarises the state of modern HF communication systems and indicates areas where some improvement can be made. The book has relatively few "errata" but my copy was missing the index from the middle of the "T's" to the end.

This book should definitely be in the possession of anyone with a serious interest in HF Communication and propagation!

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The Electrical Engineering Handbook

edited by Richard C Dorf, CRC Press, Boca Raton, Florida, 1993, 2662 pages, ISBN 0-8493-0185, US price $89.95.

As indicated in the preface, this massive document, in a single binding, is intended to provide a ready reference for the practicing engineer in industry, government and academia. The book is divided into twelve sections which encompass the whole field of electrical engineering. The ultimate goal is to signal processing, electronics, energy devices, systems, telecommunications, computers, and biomedical engineering. There are a total of 109 chapters averaging about 25 pages each but varying widely in scope and length. The writing tasks were shared by 250 authors. Each author provided anywhere from one to thirty or more literature references for further detailed information. Curiously, cross-referencing between individual chapters was absent although the uniformity of the prose and the illustrations was good.

The inevitable comparison is with the illustrious *Handbook of Physics* edited by Condon and Odishaw published by McGraw Hill over 30 years ago, revised and reprinted many times since. My general impression is the Electrical Engineering Handbook does not have the same continuity in the coverage which might be attributed to the fewer number of authors and the greater emphasis, in the Physics Handbook, on basic principles. But the handbook under review wins hands down on providing ready-to-use data for design of actual systems.

This reviewer does not feel inclined nor qualified to give an overall evaluation of the technical merits of each chapter. But on perusing chapters, where I had some familiarity with the subject matter, I came across a number of lapses, omissions and annoying misprints. For example: on page 908, the electromagnetic shielding formulas do not specify clearly what their limitations are; on page 983, the field solutions for the graded index fibers are not exact solutions of the scalar wave equation although they may be good approximations for the purpose at hand; on page 1370, the definition of ERP (effective radiated power) is vague and apparently incomplete because it does not account for the all important ohmic losses in the ground in the vicinity of the broadcast antenna; on page 977, eqns 40.5c and d are incorrect as written, obviously they should be div $E = 0$ and div $H = 0$; also there is a sign error in eqn 40.7; on page 1219, the 1926 equations of Carson are only approximate and will be inadequate for higher frequencies for radio transmission over power lines for resistive soil (here the mixed units of feet and meters are unfortunate). But these are relatively minor shortcomings. All in all, I would say the customer is getting a real bargain, on a cents-per-page basis, in making such a purchase.

James R. Wait, Review Editor

BOOK REVIEWS

Wave Physics, Oscillations-Solitons-Chaos

by Stephen Nettel, Springer-Verlag, Berlin, London, New York, etc. ISBN 3-540-55715-6, 1992, US$39.00, 244 pages, hard cover.

This relatively slim book written by Professor Nettel is a pleasure to read. The author's hope, that the book will be of use to undergraduates in Physics and of interest to others such as professors looking for exam problems, will certainly be met. The presentation is a very nice blend of mathematical rigor, physical understanding and real world examples. Exercises are sprinkled throughout the text. They should be particularly suitable for honour undergraduates in physics who plan to go on to postgraduate research. In fact, I would think the material would be highly suitable to test the more robust engineering undergraduates and help offset the recent trends, imposed by curriculum committees, to attenuate basic physics courses in favour of computer-oriented design courses with little physical insight gained.

The bulk of the book deals with the classical development of the physics of waves in a linear setting. The mathematics is handled at a somewhat higher level than would be expected for undergraduates but the informal and engaging style is guaranteed to maintain the reader's interest whether he or she is a fresh bright student or a mature researcher. The latter would greatly benefit from even a casual reading as this reviewer will attest.

The specific topics considered are : Mathematical foundations including a nice introduction to generalized functions, Natural motions and oscillations, Waves on stretched strings, Maxwell's equations and vector potentials, Physical optics and diffraction and refraction, Wave mechanics and the wave-particle duality and the loss of determinism, Linear and nonlinear surface waves on water, Solitons, Inverse scattering, Chaos and order, and Fractals. These latter (nonlinear) topics were covered mainly by Professors A V Gaponov-Grekhov, M I Rabinovich and M C Gutzwiller.

At the price indicated, this is a good buy at least compared to other recent books on similar topics from other publishers not named here.

James R. Wait
Review Editor

Spatial Dispersion in Solids and Plasmas

edited by P Halevi, Elsevier Science Publishers, 1992, xiii + 681 pages, 305.00 (Dutch) Guilders, US$180 (approx), ISBN 0-444 87405 4.

This is Volume 1 of a new series on *Electromagnetic Waves: Recent Developments in Research*. According to the editor, review articles, to be published in this book series, will cover new developments in research on electromagnetic wave phenomena. The material to be considered will include such things as waves in transparent crystals and glasses, semiconductors, metals, plasmas, and liquids. The wave propagation may occur at the surface or in the bulk of the material. The editor Prof Halevi says "the subject will cut across most of the spectrum of electromagnetic waves". It is interesting to note that in this Vol 1 of the newly announced series, there is no mention of the six volumes already published by Elsevier in the series: "Progress in Electromagnetic Research" whose Editor-in-Chief" is Professor J A Kong of MIT. Although the emphasis may be different, there is a notable overlap in the content and scope in these two book series. Indeed, Vol 6 in Kong's series, edited by A Priou†, is entitled "Dielectric Properties of Heterogeneous Materials". It contains many topics discussed in Halevi's Vol 1.

The volume under review here deals with spatial dispersion as opposed to the better known frequency or temporal dispersion. For example, in this latter case, we regard the bulk conductivity and permittivity of the material as a function of frequency which, in the time domain, leads to a convolution integral description. That is, the transient response, at a time t, depends on the prior history of the event. Thus, it would be inappropriate to say that the conductivity is a function of just t. In the case of "spatial dispersion", the conductivity and permittivity depend on the wave vector of the excitation in the spatial spectral domain. In the corresponding real space domain, the response is then expressed in terms of convolution integrals over dimensional variables. In other words, the response, at a point P, depends not only on the excitation at that same point, but also at neighbourhood points. Such non-local effects play a role in a wide range of known physical phenomena such as : rotation of light in anisotropic crystals, coherence length in super conductors, the anomalous skin effect in metals, collisionless damping in plasmas, "additional" waves in semi-conductors and excitation of longitudinal plasmons in thin films. The reviewer could also add to this list taking examples from classical electromagnetics. The first one that comes to mind is the averaged boundary condition or effective surface impedance for a wire mesh screen. The presence of tangential derivatives of the field quantities is a manifestation of spatial dispersion.

The volume has a very readable introduction (109 pages), by Fuchs and Halevi, which presents a unifying view of the subject and it facilitates the comprehension of the following 11 chapters. These authors are : N F Cramer, I J Donnelly, G E Eliasson, R Fuchs, R R Gerhardts, M G Haines, P Halevi, P Hawrylak, E A Kaner, A A Krokhin, T Lopez-Rios, N M Makarov, B G Martin, V T Petrashov, J J Quinn, A Shivarova and R F Wallis (listed alphabetically). The first 10 chapters deal explicitly with electromagnetic wave (polariton) propagation in the bulk, at surfaces, in thin films and superlattices, in spheres and on cylinders. Chapter 11 deals with laser-induced inertial confinement fusion and specifically nonlinear and non-local heat flow.

The book, as a whole, is clearly directed to researchers in solid state physics but electromagneticians of the URSI ilk would benefit greatly from the contents particularly the excellent summarising introduction by Professors Fuchsia and Halve. Also the 11 supporting chapters all contain important material relevant to scattering from non-ideal targets. For example, the chapter 5, by Fuchsia, entitled "Theory of Spatial Dispersion in Small Particles", deals with the non-validity of Mie-Lorenz theory when the radius of the particle is of the order of 50 Angstroms.

Apart from its sheer size, the book is attractively produced. The illustrations are exceptionally well done with very clear labelling. The literature reference lists are extensive (but article titles not given). Only a few references are later than 1987. The price is high but institutional libraries at major industrial and academic canters should consider it a worthy purchase. Most individuals will have to wait for the hoped-for paperback edition.

James R. Wait
Review Editor

Nonlinear Optics

by D L Mills. Springer Verlag, Berlin, Heidelberg, New York (1991).

The field of nonlinear science, which has come of age over the past decade, is to some degree floating free of its roots. Problems of technical interest to the practitioners abound and often dominate the pages of conference proceedings, research monographs, and even textbooks. Thus it is a pleasure to read *Nonlinear Optics* By D L Mills, which discusses solitons and chaos but remains firmly within the context of the optics laboratory.

Subtitled "Basic Concepts" this book includes within its 184 pages clear descriptions of both linear and nonlinear dielectric response, harmonic generation, wave mixing and Raman scattering. Even without the discussions of solitons and chaos it would be a useful introduction to modern optics, but Chapter 6 on self-induced transparency and its relation to the sine-Gordon equation sets the tone for a much broader picture. Chapter 7 considers wave propagation on optical fibers in relation to the ubiquitous nonlinear Schrödinger equation, solitons of which are probably the most important fruits of nonlinear science. A final chapter introduces the concept of chaos in relation to Duffing's oscillator and briefly describes some experimental observations of chaos in the optical laboratory.

With two appendices, thirty-two figures, and problems at the end of each chapter, **NONLINEAR OPTICS** is an ideal text for a senior or introductory graduate level course in modern optics. It should also be of value to the research scientist who wishes to get a balanced view of the important field.

Alwyn Scott
The Technical University of Denmark

Acoustics of Layered Media 1992

Part I: Plane and quasi-plane waves by L.M.Brekhovskikh and O.A.Godon (both at the Shirshov Institute of Oceanology, Moscow), , 240 pages, 44 figs., hardcover, ISBN 0-387-51038-9, US$83.00.

Part II, Point source and bounded beams, 395 pages, 42 figs., hardcover, ISBN 0-387-52646-3, US$89.00

These are vols 5 and 10 of the Series on Wave Phenomena published by Springer-Verlag, New York and Berlin. People who are familiar with Brekhovskikh's "Waves in Layered Media" (Academic Press, 1st Ed. 1961 and 2nd Ed. 1980) will find considerable similarity with these Parts I and II published as separate books. The emphasis is now on scalar acoustic wave propagation with particular applications to underwater sound phenomena. But the methods are clearly relevant to electromagnetic waves at high frequencies where the vector nature of the fields do not play a crucial role. The authors do deal with elastic waves in solids but the direct correspondence with electromagnetic waves is not simple.

In Part I, some of the topics treated are: plane waves in discretely layered fluids, moving media, reflection from special profiles such as the Epstein layer, Airy functions and their use for dealing with general graded profiles and critical reflection, reflection from boundaries between liquids and solids, matrix propagators, reflection of sound pulses, absorbing anisotropic media, geometrical acoustics and WKB approximations, reflection from a weak interface, and a critical look at the Born approximation.

In Part II, the subject matter can be read and understood without reference to Part I but this reviewer suggests that it helps to have the earlier volume at your finger tips and maybe also "Waves in Layered Media". Topics in the second volume include: spectral representation of a spherical wave, more on weak boundaries, bounded beams and total reflection, Goos-Hanchen shift, lateral waves including the moving media case, directional sources, many "exact" fields solutions, reciprocity and the flow reversal theorem, phase and group velocity of normal modes in various acoustic waveguides, thorough study of caustics and treatment at the cusp, range dependent waveguides and mode coupling, three dimensional waveguides and horizontal ray diffraction effects, the parabolic equation method for dealing with tapered waveguides, and effects of density inhomogeneities on shear waves. At the end of Part II, there is an excellent appendix dealing with the asymptotic evaluation of integrals.

Both volumes have numerous references including those to papers from the Russian (and formerly Soviet) literature but unfortunately titles of the articles are not given. A good feature is the partial listing of the sources for the English translations.

The writing style and the analytical developments are very clear throughout both volumes. I believe these two volumes will be suitable for a graduate level course in applied physics or engineering science but they will be best known and respected as a standard reference on wave propagation theory. However, I will want to keep my well worn copy of "Waves in Layered Media" in spite of the fact there is considerable overlap in the subject matter.

The prices on these volumes are not cheap but they should be affordable by any respectable university library and the individuals who can still make such purchases on their grants or contracts.

James R. Wait
Review Editor

Diffraction Effects in Semiclassical Scattering

by H. M. Nussenzveig. Cambridge University Press, 238 pages, hard back, ISBN 0521 383188, 1992, Price US$60 (approx).

Many will have seen a beautiful article by this author, in Scientific American (vol 236, p.116, 1977) on the basic physics of rainbows, coronas and glories. The simple unadorned explanations of these wonders of nature in that article would make an excellent preface to this book.

A quotation from Lord Rayleigh (the 4th Baron) is in order here: "The full solution of the problem presented by spherical drops of water would include the theory of the rainbow, and, if practicable at all would be a very complicated matter". Professor Nussenzveig had taken up the challenge and published a number of significant and original papers in the mathematical physics journals that may have escaped your notice. Some will say this all looks like resolving the Mie-Lorenz problem of scattering from a dielectric sphere. But such a formal solution given in terms of zonal harmonics is almost useless to bring out the myriad physical phenomena associated with all that happens when the sphere becomes large compared with a wavelength.

The author begins by describing the various critical effects in classical scattering which occur when the standard approximations break down. These are associated with forward peaking, glories, rainbows, orbiting and resonances. Some of the specific topics which follow are: relevant geometrical optics and classical diffraction theory for the corona, wave optics theory for the rainbow and asymptotics, geometrical theory of diffraction and the glory, complex angular momentum concepts and approximations, scattering by an impenetrable sphere and Fock's theory, tunnelling effects and reinterpretation of Fock's formulation, The Debye expansion and higher terms, Regge poles (first discovered by G.N.Watson), the rainbow as a diffraction catastrophe, the forward optical glory, and the complex angular momentum explanation of the "ripple" in calculated Mie scattering patterns. If this isn't enough, the author also discusses applications to radiative transfer, to astronomy, to seismology, to particle physics, and to linear and non-linear optics.

The numerous mathematical derivations are presented in a very concise fashion which explains why the book is only 238 pages. But the author does provide many physical explanations of the results. His keen insight to the subject is very evident in the manner of the presentation which is attractive throughout. Numerous and detailed references are given to the supporting journal literature.

The book is highly recommended to those involved in radio propagation research and radar cross-section studies. Such people are probably not aware of the vast literature on this subject that is not on their reading lists.

James R. Wait
Review Editor

Geophysical field Theory and Method, Part A

by Alexander A Kaufman. International Geophysical Series, Volume 49, Part A, Academic Press Inc., New York, 60 Figures. ISBN 0-12-402041-0 (Vol 1)
Price: US$139 577 pages

The major contribution of this book is the theoretical treatment of several important geophysical problems and methods which have scant recognition elsewhere. These problems include solid angles, geometric field models, the gravity of spherical shells and of one, two and three-dimensional bodies, upward continuation, and various aspects of electric and magnetic fields. Coulomb's and Ohm's Laws form the basis of the electrical chapter. The Biot-Savart Law forms the foundation in the chapter on magnetics. Alternating fields are not considered, but they will be treated in Volume 2 of the series.

The first quarter of the book consists of mathematical developments, followed by a smaller chapter on the gravitational field. The next third of the book is a rather thorough treatment of electrical fields as they are used in exploration geophysics. The final third of the book reviews magnetics in good detail.

Inversion is brought out in the gravity chapter, but is not followed up later. The author consistently uses rigorous analytical solutions of boundary-value-type problems. Geophysical interpretational aspects of geophysical problems is emphasised. Numerical methods are not reviewed; left for treatment elsewhere.

The anticipated reader-level is approximately that of a senior undergraduate or a beginning graduate student, and it is apparent that the book is primarily intended for use as an exploration geophysics text and reference. Many interesting cases and examples are presented, but unfortunately no exercises or problems sets. The level of the book is similar to, but more advanced than, Feynman's 1963 Lectures on *Physics* series with a strong geophysical flavour.

The occasional diagrams are illustrative sketches, without great detail. Sufficient but sometimes overly simplified when applied to the heterogeneous geophysical earth.

The units of the various physical parameters are discussed, which is not always done in this type of theoretical development. The sometimes enormous range in actual earth properties is brought out. Non-geophysicists are made aware of units and physical property matters, because the application of certain theories to real problems may not always be practical.

This is a valuable book in exploration geophysics, and will also be useful to persons in related fields.

John S Summer
Department of Geosciences
The University of Arizona
Tucson, AZ 85721, USA

Prof John Summer is the author of "Principles of Induced (electrical) Polarisation for Geophysical Exploration", Elsevier, 1976 which is now regarded as a classic. Professor Summer, and his wife Nancy, died in a plane crash in northern Mexico on June 4, 1993, a few days after I received this review. ***J. R. Wait*****, Review Editor**

† see review in the Radioscientist Vol 4, No 1, p26

Note from the Review Editor

If you are interested and willing to review books for the Radioscientist, send me a complete description of the item and the name (and address if possible) of the publisher. Publication dates should be 1992 or 1993. **Of course, you may keep the book after you have fulfilled your commitment.**

Mail reply to:

James R. Wait
2210 East Waverly
Tucson AZ 85719-3848,
USA.

Fourth International Conference on Ground Penetrating Radar (GPR)

8-13 June, 1992, Rovaniemi, Finland, Geological Survey of Finland Special paper 16. ISBN 951-690-463-7, GSF Pub. Sales, SF-02150, Espoo. 490.00 Finnish Marks including postage and handling (365 pages paperback).

This attractively produced compendium of conference papers represents another milestone in this rapidly developing field. As indicated in the preface, the articles were approved for publication "solely" on the basis of abstracts submitted to the scientific committee consisting of S E Hjelt, P Hanninen, J S Mellett and P U Uliriksen. But apparently many of the papers were later edited by Pauli Hanninen and Sini Autio. There are 45 articles representing contributions from the international community of GPR investigators. The general topics are : Geological applications, civil engineering applications, instrumentation and related research investigations mostly of an experimental nature. Much attention was paid to data processing techniques. There are also many case histories which are accompanied by colourful and clear illustrative examples such as direct plots of sub-surface time delays versus lateral displacement along the surface.

It is apparent, at least to this reviewer, that this is a subject where theory greatly lags the experimental techniques. While it is true, much useful information can be gleaned from the observed data, it seems that quantitative understanding and further insight will come from analytical studies of such things as allowing for the dispersive nature of the transmission medium such as caused by the appropriate frequency dependence of the conductivity and permittivity of the medium. Also it seems that people working in this field have not exploited or even are aware of the vast literature on the use of transient electromagnetic waves in mineral exploration such as reviewed in considerable depth in the Special Issue of *Geophysics* (Aug 1984) on the subject "Time Domain Electromagnetics" edited ably by Misac Nabighian. I was also disappointed that there was little discussion of the antenna design which is not a trivial subject because of the close proximity of the radiating structure with the lossy propagation medium. The few papers which did touch on this issue contain material already in the journal literature such as the paper by G A Burrell and L Peters in the Proc. IEEE July 1979 Special Issue on "EM applications in geophysical exploration" edited by this reviewer.

It is a pity that none of the discussions of the participants at the meeting are summarised in this document. Nor were there any substantive review or summarising papers in the publication.

In spite of the indicated shortcomings noted above, I believe workers in the field will need to have access to this publication. The price is high but not outrageous (i.e. approximately US$100).

James R. Wait
Review Editor

Seismic–VLF Effects

The subionospheric propagation of Omega VLF signals transmitted from Hawaii and received in Japan, has been utilized to find the seismic effect (seismo-Trimpi effect). Perturbations in VLF propagation have been identified for some strong earthquakes.

The satellite (Intercosmos-24) observation of ULF and ELF/VLF radio noises in the ionosphere have yielded that ULF waves tend to be observed mainly before the earthquakes and over the subsequent earthquake epicenters, but VLF/ELF emissions appear in a wide longitude range. These characteristics are interpreted in terms of the generation of ULF waves in the ground, their penetration into the ionosphere, and interaction with protons, and the associated proton precipitation.

The seismic effect in whistler propagation has been found by means of the long-term whistler data, and it is found that whistlers with larger dispersions tend to occur as a precursor of earthquakes.

The wave distribution function method has been developed to determine the distribution of wave energy density of VLF waves at the ionospheric base on the basis of the simultaneous measurements of three field components. A very objective method is proposed to yield the most optimum wave distribution function by the combined use of Philips-Tikhonov regularization and generalized cross validation.

Lightning-induced particle precipitation is being studied by using the Trimpi effects detected by subionospheric VLF propagation and the simultaneous direction finding of whistlers. The data were obtained in the VLF campaign in Ceduna in Australia, and the Trimpi data by Professor Dowden.

M. Hayakawa
University of Electro-Communications
Chofu, Tokyo.

[Reprinted from VERSIM, JULY, 1993. There will be an international workshop on Electromagnetic Phenomena related to Earthquake prediction, held in Tokyo right after the URSI General Assembly.]

A Global HF Radar Network for Imaging High-Latitude Convection

Over the past several years, a new international initiative has been started by members of the Dual Auroral Radar Network (DARN) ground-based experiment team of the ISTP/GGS project. DARN was originally proposed to the NASA OPEN mission as a network of VHF E-region coherent-backscatter radars that would provide ground-based measurements of high-latitude convection to complement OPEN satellite observations. As the NASA OPEN mission evolved into ISTP/GGS, the DARN concept also evolved with the development and successful operation of phased-array HF radars such as those located at Goose Bay, Labrador; Halley, Antarctica; and Schefferville, Quebec. These radars require decameter-scale electron density irregularities to be present in the high-latitude E or F-regions for backscatter to be observed. For the dominant F-region observations, these radars have proven to have several advantages over their VHF counterparts. Notably, they have much larger fields-of-view, their Doppler observations are more readily related to F-region plasma drift motions, and there is no apparent velocity threshold for the F-region irregularities to be created.

To this point, most — albeit not all — of the results from HF radars on ionospheric convection have been obtained with single-radar scanning techniques. In this mode of operation, a single radar is pointed into two or more different directions to obtain Doppler information from which velocity vectors can be estimated subject to certain assumptions. For SuperDARN, the HF radars will be operated in pairs and obtain common volume measurements from different viewing directions. This is a mode which has been reported recently using the Goose Bay and Schefferville radars. It is also similar to the operation of the STARE and SABRE VHF radars in Scandinavia and the BARS radars of the CANOPUS network in Canada. Bi-directional common volume measurements yield two-dimensional images of the plasma drift pattern that are based upon *definitive* vector velocity determinations at each location in the common field-of-view for which irregularities are present.

The SuperDARN concept also seeks to expand the observation of plasma drift patterns to a global scale by utilising a network of pairs of HF radars extended in longitude in the northern hemisphere and at conjugate locations in the southern hemisphere. Figure 1 shows the combined fields-of-view of the currently-funded northern-hemisphere elements of SuperDARN. The sites for these radars and their anticipated start of operations are given in the table below.

Location	**Geographic Coordinates**		**Initial Operation**
Saskatoon, Sas, Can.	52.2° N	-106.5° E	Spring, 1993
Kapuskasing, Ont, Can.	49.4° N	-82.3° E	Spring, 1993
Goose Bay, Lab, Can.	53.3° N	-60.5° E	Operational
Iceland West	64.4° N	-22.0° E	Autumn, 1993
Iceland East	TBD		Summer, 1994
Finland	TBD		Summer, 1995

Additional sites in North America are being considered in British Columbia in Canada and at King Salmon, Alaska. However, funding is not currently available for either of these additional sites. Discussions have also taken place with Russian scientists concerning potential sites in their country. While there is no current funding for the Russian radars, it is interesting to consider a northern-hemisphere SuperDARN network consisting of 12 radars, four of which would be located in Russia.

In the southern hemisphere, there is one HF radar in operation, namely the PACE radar at Halley Station, Antarctic (75.5° S -26.6° E). Two additional HF radars are being proposed; one is a collaborative South African-British-U.S. radar to be located 100 km polewards of the existing SANAE site and the other is a Japanese HF radar to be located at Syowa Station. A plan view of Antarctica showing the fields-of-view of the existing and planned systems is given in Figure 2.

The Principal Investigators (PIs) for the funded elements of SuperDARN and their respective funding agencies are as follows (next page):

SUPERDARN

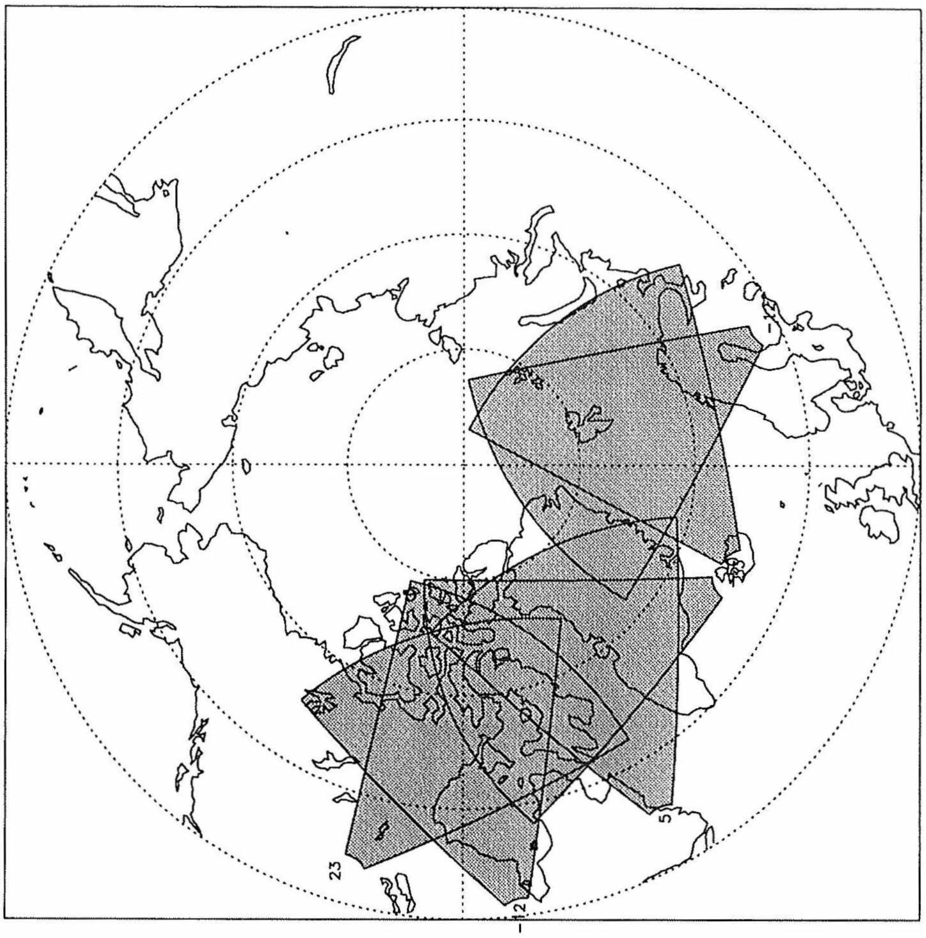

Fig. 1. Combined fields of view of currently funded Northern Hemisphere SuperDARN elements.

Saskatoon
Prof. George Sofko
Institute of Space and Atmospheric Studies
University of Saskatchewan
Saskatoon, Saskatchewan S7N 0W0
Canada
E-Mail: CANSAS::Sofko
Saskatoon is funded by the Natural Sciences and Engineering Research Council (NSERC) of Canada

Kapuskasing and Goose Bay
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The Johns Hopkins University/Applied Physics Laboratory
Johns Hopkins Road
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USA
E-Mail: APLSP::Greenwald
Kapuskasing is funded primarily by the National Aeronautics and Space Agency (NASA) with additional support from INSU; Goose Bay is funded by the National Science Foundation (NSF)

Iceland West
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Iceland West is funded primarily by INSU with additional support from the NSF

Iceland East and Finland
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This is funded by the Science and Engineering Research Council (SERC) with additional possible funding from Finland and Sweden

Halley
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E-Mail: 19989::Dudeney

Halley is funded by the Natural Environment Research Council (NERC) and NSF.

The SuperDarn radars will operate continuously providing a global-scale diagnostic of the electrodynamic state of the high-latitude ionosphere. Data from the northern hemisphere radars will be collected at JHU/APL where it will be merged onto high-capacity exabyte tapes and distributed to the PIs in the participating countries for subsequent redistribution to interested scientists. Selected portions of these merged tapes will also be made available to national data centres to support the activities of national and international research programs including STEP. Data will also be processed in real-time at the radar sites to produce Key Parameters that will be submitted to the NASA ISTP/GGS central data handling facility (CDHF) within 24 hours of acquisition. Data from the southern hemisphere radars will be collected at BAS where similar merging and distribution processes will take place. Merging of the full data suites from the southern hemisphere radars will not take place until the optical disks are retrieved from Antarctica, approxi-

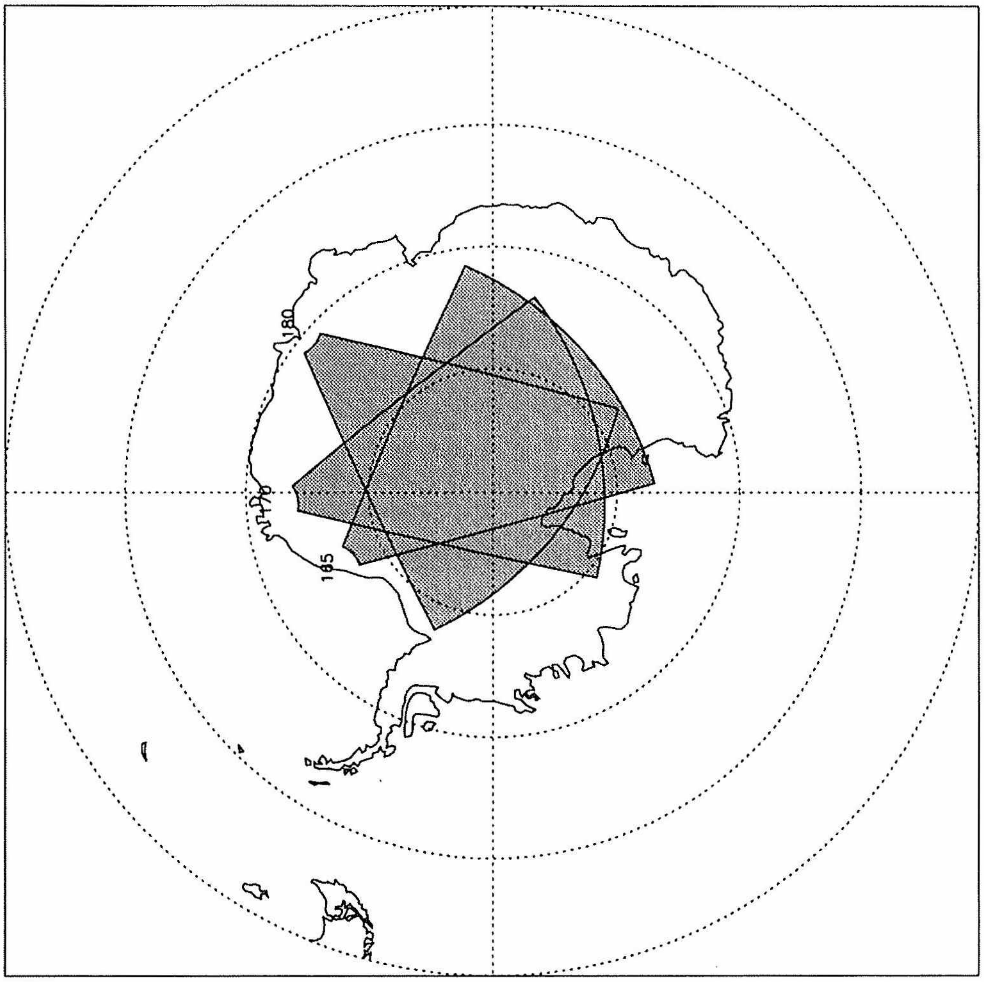

Fig. 2. Plan view of Antarctica with fields of view of existing and planned systems.

mately one year after the data are acquired.

The SuperDARN investigators have identified three categories of operation:

Common Programs: Several standard operating modes of the radars for which all radars will be operated in the same manner. Common programs will comprise 50% of the total operation.

Special Programs: Special operating modes agreed upon by the PIs for the purpose of achieving specific research goals. Special programs will be limited to 20% of the total operation.

Operations: Time set aside for the PIs to pursue personal or collaborative research goals. Discretionary time will comprise the remaining 30% of the radar operations.

Over the past several years, data from the existing elements of the SuperDARN network have yielded contributions to wide-ranging topics in solar-wind—magnetosphere—ionosphere—atmosphere coupling. These have included the IMF B_y-dependence of dayside convection patterns, the identification of the dayside cusp, the observation of flow bursts in dayside convection, the identification of large-scale nightside oscillations in convection apparently associated with magnetospheric cavity modes, and the identification of sources of high-latitude atmospheric gravity waves. As the SuperDARN network evolves it is anticipated that it will yield increasingly refined data on the global extent and evolution of ionospheric irregularities, ionospheric convection, and high-latitude gravity waves. The data from the network will be of significant value to any investigation into the large-scale dynamics of solar-terrestrial coupling processes. Consequently, the SuperDARN team welcomes any inquires and/or suggestions from the satellite, ground-based and theory communities into the potential application of the network.

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SOLAR RADIO ASTRONOMY AT TREMSDORF

Fig. 1. View of the antenna site at the Observatory of Solar Radioastronomy in Tremsdorf. The radio spectrograph uses three of the parabolic mirrors (10.5 m, 7.5 m, and 4 m diameter) with crossed logarithmic-periodic feeds. Observations between 40 and 100 MHz are recorded by the double-structured, logarithmic-periodic Yagi aerial in the background right of the main building.(photo: R. Engler, public relations).

Modern radio astronomy in Germany began relatively late after World War II. In the eastern part of Germany O. Hachenberg at the "Heinrich-Hertz-Institut fur Schwingungsforschung in Berlin" and H. Daene at the "Astrophysikalisches Observatorium Potsdam" initiated the first successful efforts in solar radio astronomy. On the agreement of both institutes in June 1953, the work in the microwave region and in the meter and decameter wave region was concentrated at the "Heinrich-Hertz-Institut" in Berlin and at the "Astrophysikalisches Observatorium Potsdam", respectively. The evolution at both sites has proceeded relatively independently.

The first attempts to receive solar radio radiation trace back to the year 1896. In Potsdam J. Wilsing and J. Scheiner reported their results in the journal "Astronomische Nachrichten" [1]. Although they were unsuccessful in establishing the existence of solar radio emission, their experiments marked the birth of radio astronomy, particularly of solar radio astronomy. 58 years later, H. Daene founded — after first attempts with an 8 m dish and a 176 MHz receiver at the "Sternwarte Potsdam-Babelsberg" — the "Observatorium fur solare Radioastronomie" in Tremsdorf, about 15 km to the southeast of Potsdam and roughly 25 km south of Berlin. His intention was to record the solar occultation on June 30, 1954 in the radio wave domain. Up to now there have been excellent observing conditions. During the International Geophysical Year (1958) the Sun was observed at three frequencies (23, 113 and 234 MHz) in Tremsdorf. During the following years the polarisation of solar radio bursts was routinely monitored at several frequencies below 100 MHz for the first time. These measurements resulted in the first systematic study of the polarisation of solar type III/V radio bursts [2]. After the cessation of the observation of solar radio emission at the "Heinrich-Hertz-Institut" in Berlin in 1972, the microwave patrol receivers were transferred to Tremsdorf. From then on the Sun has been daily and routinely monitored on at least 10 frequencies in the range 23 – 9500 MHz.

At the present time, the Tremsdorf Observatory, belonging to the "Astrophysikalisches Institut Potsdam", is the only solar radioastronomical facility in Germany. The solar radio station in Weissenau (Astronomisches Institut of the University of Tubingen) located in the south of Germany was closed in 1992 after more than 25 years of continuous observations using a sweep spectrograph in the range of 100 - 1000 MHz. During the last few years a new radio spectrograph, consisting of three different instruments (cf. Table 1), was built in Tremsdorf. These are:

(i) 4 sweep spectrographs with a sweep rate of 10/s in the ranges: 40 - 100 MHz, 100 - 170 MHz, 200 - 400 MHz, and 400 - 800 MHz;

(ii) a grid of 14 single frequency polarimeters at the frequencies: 42, 64, 83, 112, 136, 164, 234, 287, 330, 380, 428, 526, 638, and 775 MHz, with a time resolution of 0.01 s and an intensity resolution of *DT/T* of 3 %, where *T* denotes the radiation temperature corresponding to the intensity *I* meas-

SOLAR RADIO ASTRONOMY AT TREMSDORF

OSRA Tremsdorf

SPECTROPOLARIMETER 40-800 MHz

3 components

4 sweep spectrographs			grid of single frequency polarimeters	two multichannel spectrographs		
ΔF (MHz)	B (kHz)		3 per range	ΔF (MHz)	B (kHz)	
			B=190...3500 kHz			
40-100	190	$\Delta t=0.1$s	$\Delta t=0.062$ s (0.01s)	12...24	190 (64 channels)	$\Delta t=0{,}01$s
100-170	300	$\Delta T/T \approx 10$ %	$\Delta T/T \approx 3$ %			$\Delta T/T \approx 3$ %
200-400	700	D=50 dB	D= 60 dB	40...80	1000 (40 channels)	D=40 dB
400-800	1700	$S_{min}=2$ sfu	$S_{min}=0{,}5$sfu			$S_{min}=0{,}5$ sfu
1 : 2				center frequency and channel distance variable; every 5. channel with pol.		
Data rate: 2560/s			2400/s	≈ 10000/s		

Data recording

now: film black/white; color TV screen; 256x256 pixels; 18 color steps — magnetic tape — not ready

in future: hard disk

STORAGE after choice (on EXA-Byte tapes).

PROCESSING PROGRAMS

ured at the frequency *f*.);

(iii) two multi-channel spectrographs with bandwidths of 12 and 40 MHz which can be chosen anywhere in the range of 200 - 400 MHz and 400 - 800 MHz, respectively. This last instrument is also called a "spectrographic microscope". This design of this three component radio spectrograph enables measurements of solar radio emission with higher spectral and temporal resolution than previous radio spectrographs. A photograph of the Observatory antenna site is shown as Figure 1.

The radio emission of the Sun is generated in the corona. Since the Sun is an active star, its radio emission has a thermal and nonthermal component. The plasma in the solar corona represents a collisionless plasma dominated by magnetic forces. The coronal radio emission in the meter wave range is generally considered to be excited near the local plasma frequency. Thus, a radio source travelling upwards in the corona, and so through decreasing plasma frequencies, show a drift in the dynamic radio spectrum from high to low frequencies. High energetic electron beams propagating through the corona produce fast drifting bursts in the dynamic radio spectra. If they travel along open magnetic field lines they are observed as the so-called type III bursts. In fact type III bursts are even recorded below 1 MHz by satellite, indicating that the electron beam enter interplanetary space. If the high energetic electron beam propagates in a closed magnetic field configuration , i.e., in a coronal loop, it produces a type U burst.

An example recorded by the new radio spectrograph in the range between 170 and 40 MHz is shown in Figure 2. It represents the radio signature of an electron beam propagating with a speed of 50,000 km/s = 0.17c in a coronal loop. The turning point at 50 MHz indicates the top of the loop located at approximately 630,000 km above the photosphere.

The coronograph LASCO aboard the ESA/NASA satellite SOHO (scheduled for late 1995) will observe the corona from 1.1 to 30.0 solar radii [4] (cf. Fig. 3). According to a special density model of the solar corona [3] the new radio spectrograph in Tremsdorf can monitor coronal radio radiation up to 2 solar radii (cf. Fig. 3). The LASCO coronograph C1 [4] and the radio spectrograph of the Tremsdorf observatory will observe the same height region of the corona as indicated in Fig. 3. The non-thermal solar radio radiation is generated by supra-thermal electrons so a solar radio spectrograph is a sensitive detector of high energetic electrons in the corona. Since the new radio spectrograph in Tremsdorf sensitively detects high energetic electrons and monitors plasma physical processes in the corona with a very high time resolution, it will contribute to the SOHO mission by ground based observations.

SOLAR RADIO ASTRONOMY AT TREMSDORF

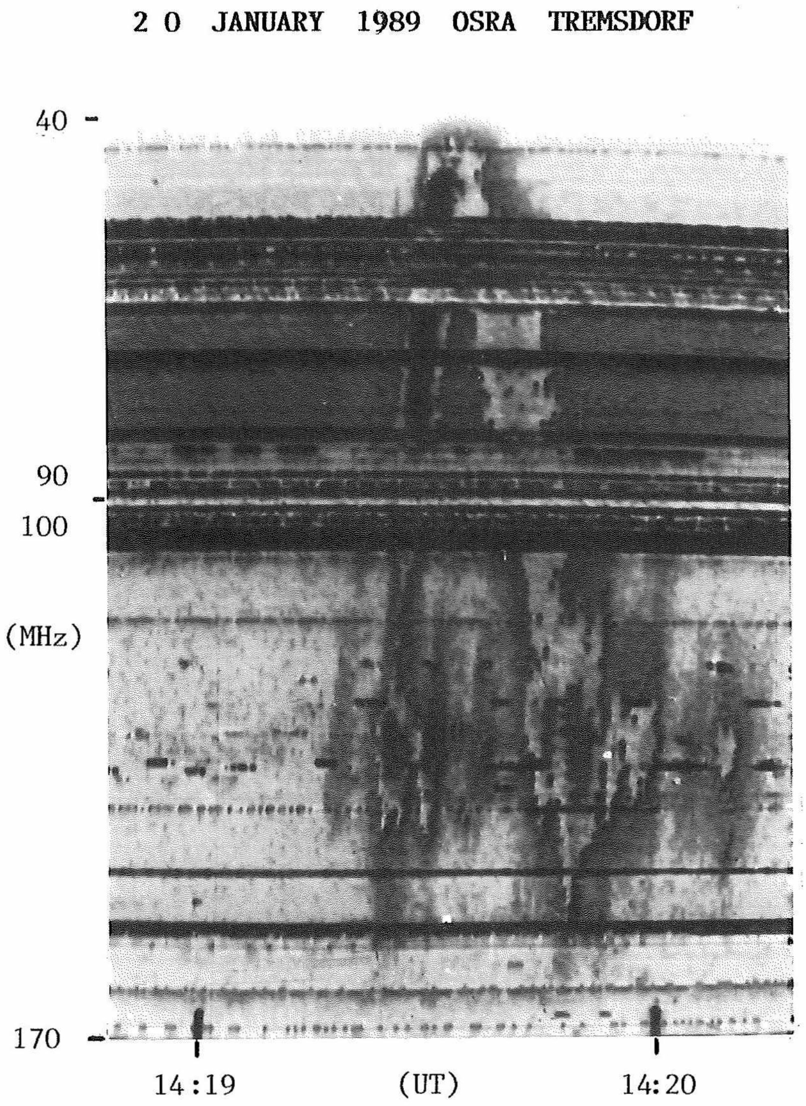

Fig. 2. Spectrogram of a solar type U burst starting at 14:19:23 UT. In the original the intensities are colour coded.

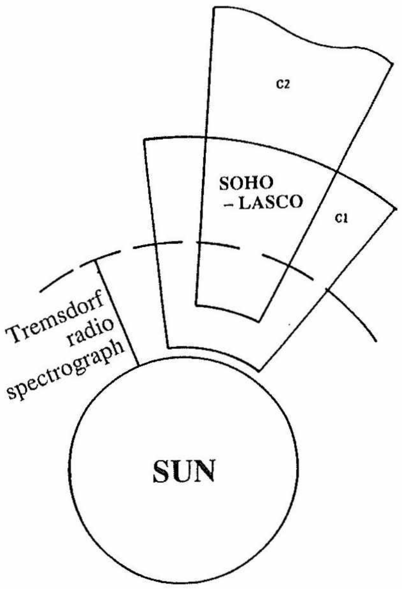

Fig. 3. The radio spectrograph in Tremsdorf is able to receive the solar radio radiation up to an height of 2 solar radii, approximately. The coronographs LASCO (C1, C2, and C3) aboard the SOHO satellite will cover the corona from 1.1 up to 30.0 solar radii [4]. In particular, the radio spectrograph in Tremsdorf and the C1 spectrograph will observe the same height region of the corona. Both data sets are highly significant to study such problems as the onset of coronal mass ejections and their connection to the flare process.

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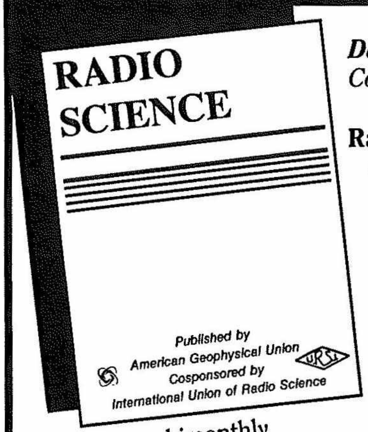
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EA3A17 6/93