The Radioscientist

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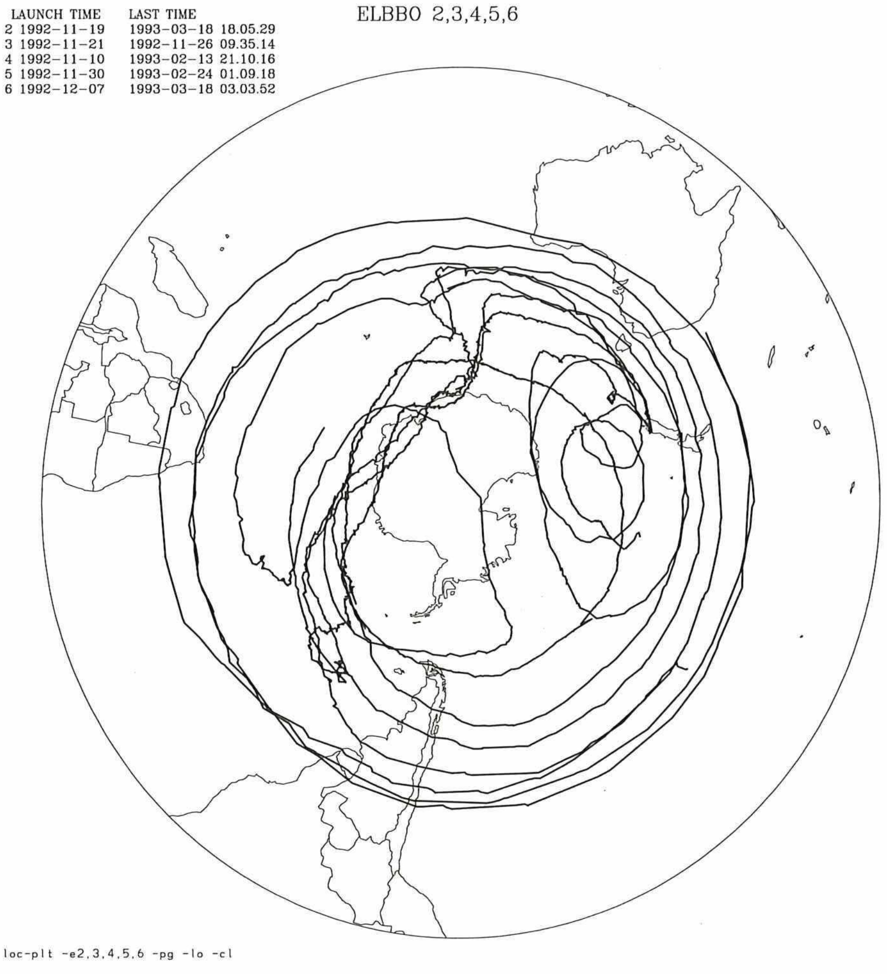

The U.R.S.I. Radioscientist

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Email (Internet to "dowden@otago.ac.nz") is fine for pure ASCII text files, and Encapsulated PostScript Files (EPSF). Ordinary PostScript is OK but requires some work by us to convert. TEX, which can also be sent by email, is of limited use since it cannot be easily used by our page layout software (PageMaker). If copy is sent in TEX it must be accompanied by a "flat" ASCII file purged of TEX commands.
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*.
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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: Tracks of the five Extended Life Balloon Borne Observatories (ELBBOs) launched from Dunedin, New Zealand, during November-December, 1992. Tracks are in a counter clockwise (CCW) direction, mostly enclosing the South Pole, until late February.

Editor's dilemma

There are important issues like individual membership which need to be discussed widely before formal decisions are made by Council at Kyoto next August. There are formal paths to Council from the Member Committees via the Board, from the Commissions and from the appropriate Standing Committees. But an important way to get these issues discussed is to air them in the *Bulletin* and *the Radioscientist*. To start discussion through the LETTERS pages, I have introduced these issues on this page. However, I have come to realise that such editorials should come from other than the Editor. Otherwise, despite the disclaimer on the page on your left, some readers will take the editorial as official URSI policy or even as "leaking" privileged discussions not ready for publication. So from now on, I hope to avoid acting this part and have the editorials written by named individuals giving their personal opinions.

Help Wanted

I am saying this here rather than in a box like an advertisement because I guess anyone keen enough to read the editorial might well like the job. Although the two "Editors-in-Chief" (the new Secretary-General and maybe me) will be ultimately responsible for the combined URSI Radioscientist-Bulletin, the real editorial work of encouraging contributed articles and of inviting articles, (occasionally) writing editorials, getting articles refereed (one referee, usually), and copy editing those articles when finally accepted for publication to conform to Radioscientist-Bulletin style, will have to be done by Associate Editors.

This job will be spread between about five or six such Associate Editors so as not to make unreasonable demands on any one person's time. There are still two or three places vacant. Each of the Associate Editors are equal in status and will have a strong voice in determining the policy and style of the new Radioscientist-Bulletin (we will meet for such discussions and decisions in Kyoto). Their most important job is promotion — **those who just sit and wait for articles to be submitted to them are not welcome!**

The responsibility for getting the illustrations (including equa tions) into machine readable form (photographs in TIFF, line drawings in EPSF or PICT) will be the Editors', but Associate Editors who can do some of this as well will be most welcome. Although URSI HQ and the printer work in a Macintosh environment, some of our present Associate Editors work in a PC environment and produce files which can be easily converted. Thus a file typeset in *Word for Windows* in *Radioscientist* style can be converted into Macintosh *Word 5* with no loss of style format. In particular, equations set in either of these (using a subset of *MathType* which is built into both forms of *Word*) convert also. The graphics for the ELBBO cover story in this issue were made on a DOS machine and emailed to me as PostScript files. Having been taught how, I converted these into encapsulated PostScript files (EPSF) for placing into PageMaker. So being restricted to a PC environment is no handicap.

If you have a strong interest, some experience, maybe some desk-top publishing skills and can be relied on to find about 20% of the content of the new *Radioscientist-Bulletin* on average (about 30 pages per year), please write, fax or email me (see masthead page inside the cover). We will have a meeting during the URSI GA in Kyoto to work out the full details.

TEX

We receive contributions in TEX quite frequently, particularly by email. These look great when printed on a laser printer, but we cannot load TEX files into PageMaker like we can the files of any(?) other word processor. Several "learned" journals accept TEX and provide a style file so that the author's file on disk will print out exactly right for the journal. In the past, this printout was physically cut out, stuck on a paste board, and photographed (after adding the journal's page numbers, running head, etc.). Many still do it this way, but we don't and cannot afford to. PageMaker and similar applications like Quark Express do this cutting, pasting, positioning and sizing all electronically.

No doubt, some of the journals which accept TEX files do all this electronically. Although it is rather involved and is not fully editible, I believe we can too. If so, we will produce a TEX style for future authors. In the meantime, *please* submit emailed copy in plain or "flat" ASCII when sending TEX files.

To Be or Not

This is not Hamlet's dilemma. Rather it is about the continued existence of URSI. It could be argued that URSI is too technique oriented to be an ISU (International Scientific Union) and that its various Commissions could be taken over by existing ISUs. If URSI did not exist and was being proposed now, this argument would probably be sustained. If you think about it, and I hope you do, you will find good reasons why URSI should continue. But the proof is in the pudding — **the various Commissions of URSI will thrive as long as URSI is where the action is**. Basically this comes down to the interest of radioscientists in and loyalty to URSI. Over the last 20 years URSI has changed, and is still changing, to enhance this. Some of these changes are the opening of URSI General Assemblies and the Symposia to all radioscientists, the individual relationship initiated as the "Network of Correspondents" in 1990 at Prague (and maybe to be extended at Kyoto), the vastly increased Young Scientist programme, and the increased profile of URSI through its sponsored symposia (particularly those carrying "URSI" in their title), sponsored journals (*RADIO SCIENCE* and another soon to be announced) and in new URSI publications like this one. It would be alarmist to pretend that URSI is in real danger of going down the tubes at present, but it could well have done so by now if the changes mentioned abovehad not occurred.

SCANNING THE ISSUE

Five balloon borne observatories (ELBBOs) launched from Dunedin, New Zealand, orbited the Earth several times in 3–4 months as their tracks plotted on the cover show. Short "beeps" from one of these suggests it is still at its designed altitude of 25 km, probably over Antarctica largely devoid of sunlight for its solar cells for power. Analysis of the radio science experiments — location by VLF remote sensing of electron precipitation from the Radiation Belts — has scarcely begun, so this article describes the data coverage and some initial results about atmospheric electricity and motion at 25 km altitude.

It is nearly a third of a century since Victor Twersky's report on an URSI symposium on electromagnetic scattering held in 1959. The report is reproduced here by optical character reading (OCR) of the original published in the July, 1960, issue of *Physics Today*, with formal permission of both the author and *Physics Today*. Conference reports are rarely exciting even when fresh, so why reproduce one so old? Read it and see why. I found it fascinating on two levels: firstly, that of the basic theory, much of it new to me, and secondly that so much could be achieved in the understanding of scattering in — and maybe because of — the absence then of fast computers for modelling and simulation. I was unable to fit in the final paragraph which I give now to make a point:

"In closing, it should be stressed that the topics mentioned here are but a few of those discussed in Toronto. By restricting attention to several areas of general interest, the intent has been to forestall the question begged in the introduction: in spite of the fact that wave problems have been studied for two hundred years, each year brings not only new analytical treatments and new practical applications, but new physical concepts as well." My question is, have we made much progress in real understanding since then?

Radio bursts from the Sun were first detected and classified into "Types" over 40 years ago. However in this short note, Treumann and LaBelle announce the first observation of a *planetary* Type V radio burst.

The study of the ionosphere is as old as URSI and was partly the cause of URSI coming to be. Having named layers D, E and F, it was found that some (F in particular) split and that another, sporadic E (Es), behaves strangely. Some order in this behaviour of Es is seen in sequential sporadic E (Ess) described by Wilkinson.

In the market economy, government research institutions are expected to be at least partly self supporting. IZMIRAN in Russia have developed sophisticated simulation and modelling software for ionospheric propagation. Demonstrations of this can be obtained free for evaluation by western scientists who may eventually wish to buy the working packages. Phil Wilkinson reviews the demonstrations and explains further.

The picture of "the Snake" on the last page of this issue looks like a photograph of part of the sky near the Galactic centre. It is, if "photography" extends to 6–cm wavelengths (unfortunately, the term "radiography" was taken by the X-ray people). Such high resolution radio imaging was not considered even a future possibility 40 years ago.

LETTER

I wish to strongly endorse Ross Stone's suggestion (p. 5, March 93 issue) that the combined publication be labelled "*the Radioscientist* and the URSI Bulletin" to ensure the essential continuity with the previous two publications. No doubt an executive decision will be made about how to identify the Vol. number for the 1994 issues. Maybe Vol. 5 would be most appropriate with the Bulletin Number, No.26?, also shown in parentheses.

I found Michael Rycroft's suggestion rather amusing. Certainly the label 'Radio Communications' would completely miss the mark unless we are catering primarily to the telecommunication and amateur radio people who already have numerous outlets for their material.

I do have a personal reason for Ross Stone's composite title. Within the past six months I have been trying to convince the Elsevier Company that, when I requested a copy of one of their books for review, I was not a private "radio scientist". Their bill for $US86 is still unpaid. As yet they will not acknowledgement my explanations. Any suggestions?

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[Ed: A mock-up combined magazine, incorporating many of these ideas, is being prepared for consideration by URSI Council at Kyoto. The Bulletin issue number and Radioscientist volume number can both be retained for continuity, using annually reset pagination. For other than formal citation, most people will use terms like "the March 93 issue" as here.]

Extended Life Balloon Borne Observatories

In November and December 1992 we launched 5 Extended Life Balloon Borne Observatories (ELBBOs) from Dunedin, New Zealand in a international program by the University of Washington, Seattle, USA, the University of Otago, Dunedin, New Zealand, and the INPE, San Jose dos Campos, Brazil. The program involved the design, fabrication and launch of balloon-borne payloads on superpressure balloons into the stratosphere to study atmospheric and space electrodynamics. Each of the three groups provided the instrumentation for the following measurements: vector electric field and associated parameters such as the conductivity (U. Washington); VLF hiss and sferics, and detection and capture of Trimpis from VLF MSK transmitters (U. Otago); and X-rays (INPE). Very similar instruments were used to measure Trimpis at ground stations. The design and fabrication of the basic payloads and nearly all other "engineering" requirements were make by on behalf of the Washington group on funding from both NASA and NSF. The Otago

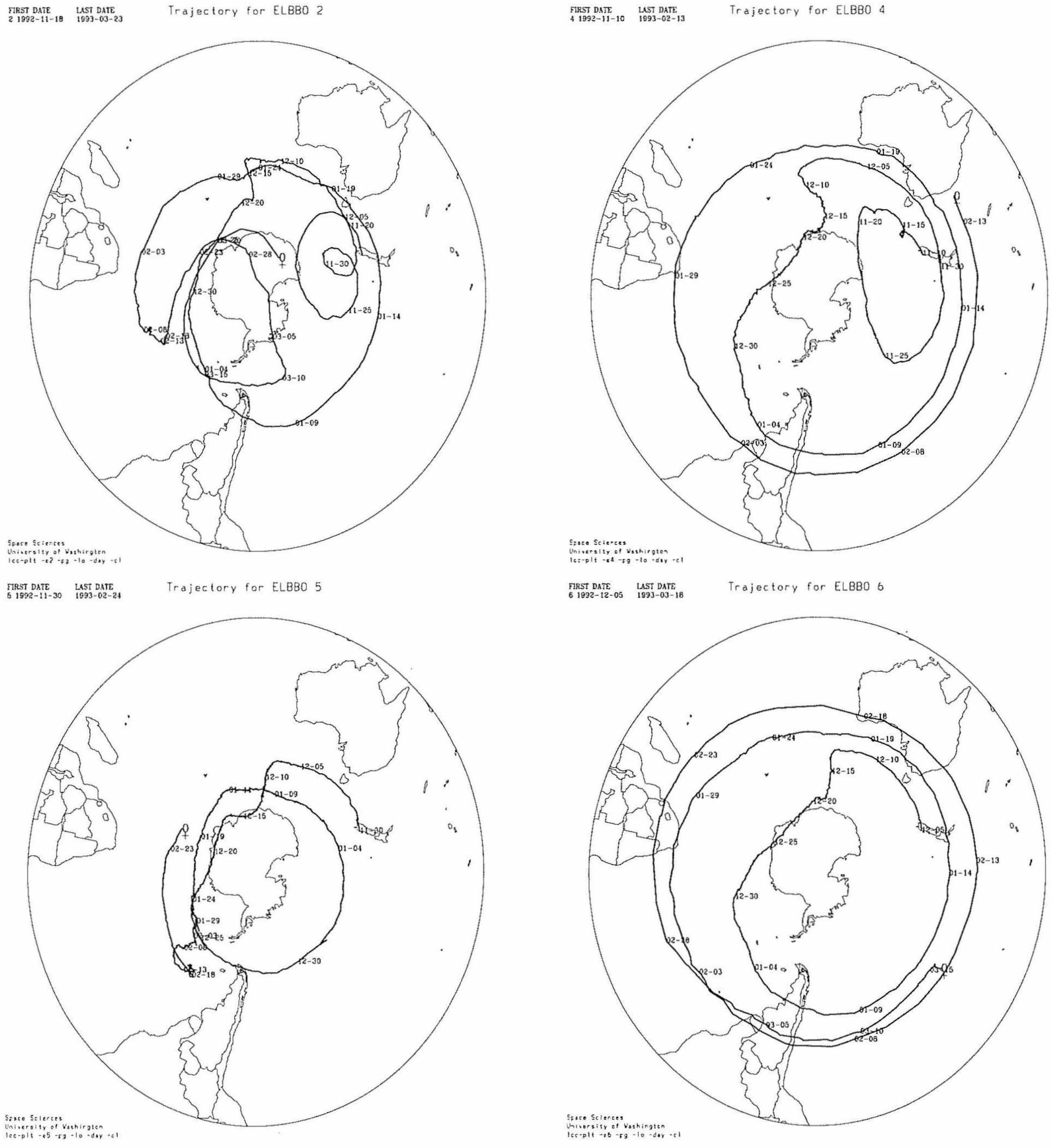


Fig. 1. Trajectories from four superpressure balloons launched from Dunedin, New Zealand in November and December 1992. At the time of this plot all these balloons were still floating at the design altitude of about 25 km.

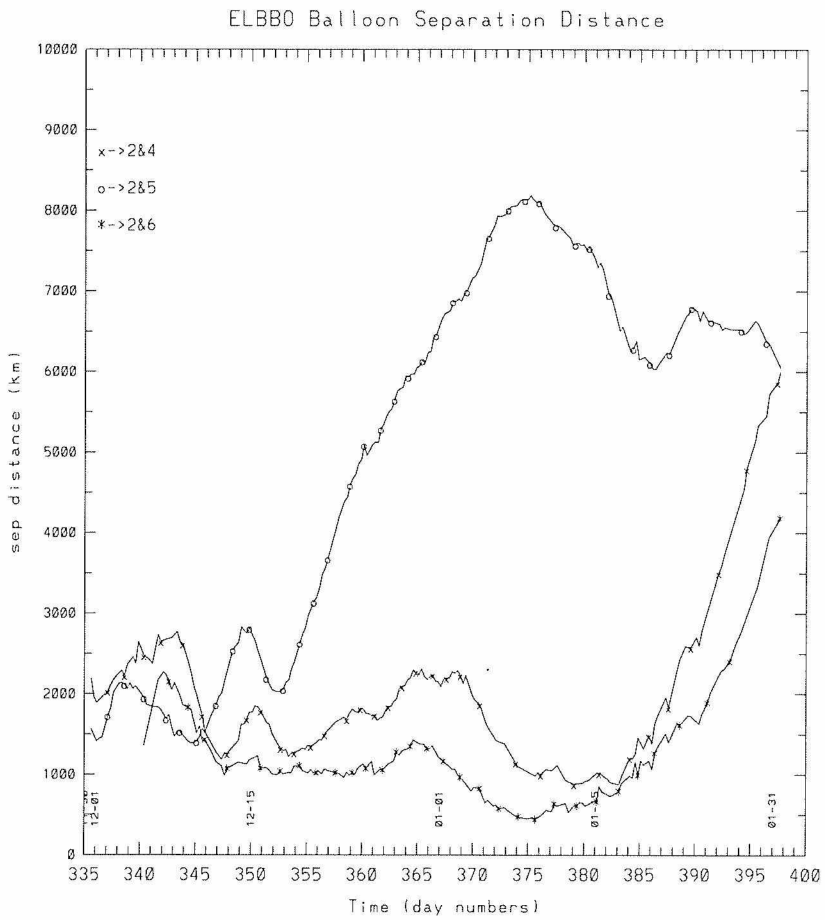


Fig. 2. Sample separation distances for three of the balloons in Figure 1.

group designed and provided the HF telemetry and ground reception stations, the non-linear heat diodes (for thermal control of the payloads) and the Omega navigation and ELBBO velocity measurement. (Telemetry and ELBBO tracking was also provided by satellite though ARGOS).

Of these 5 ELBBOs, 4 remained aloft for 3 months or more collecting good data. The longest flight lasted well beyond the 4–month span shown in Figure 3 and is possibly still (as of mid-May) going. The fifth flight had a balloon malfunction, immediately apparent after launch, and only lasted 4.7 days.

Data Coverage. The cover of this issue shows plots of the trajectories of all of the ELBBOs. All longitudes were covered several times over and latitudes covered ranged from low (< 30°) to

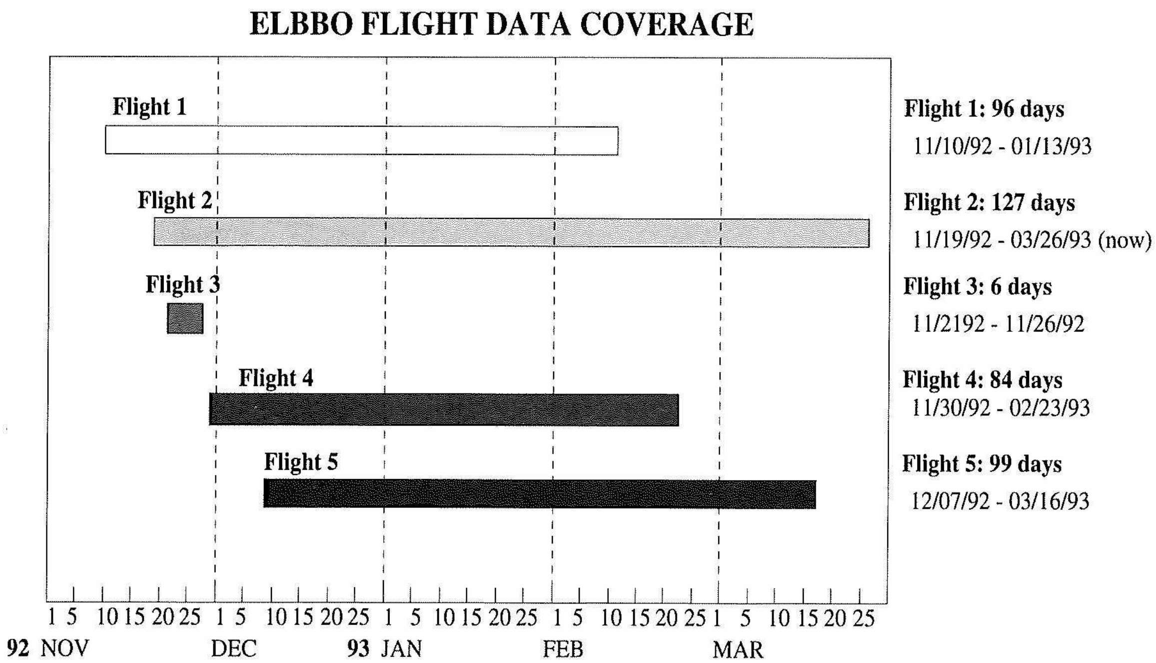


Fig. 3. Total ELBBO data coverage as of 26th March, 1993. These plots are listed in order of launch in this ELBBO Main Flight Sequence. The payload numbers are different from the flight numbers because the payload numbers correspond to particular hardware. The relationship between the in Figures 1&2 and the flight numbers in this figure is as follows: Flight1 = ELBBO4, Flight2=ELBBO2, Flight3=ELBBO3, Flight4=ELBBO5 and Flight5=ELBBO6.

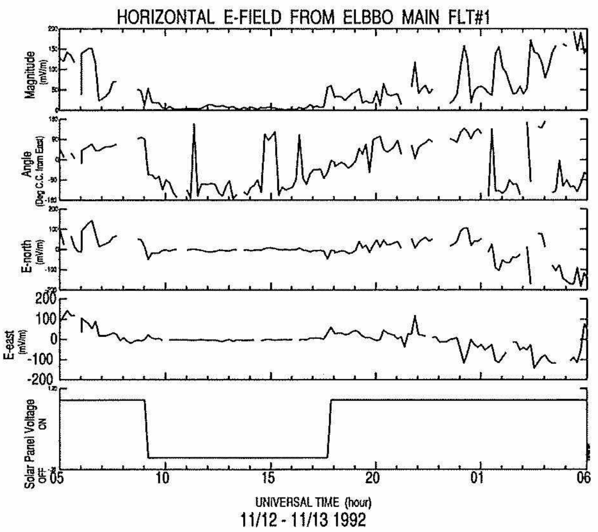


Fig. 4. Horizontal vector electric field from ELBBO4 for one day. The top two panels are the magnitude and angle of these data. The next two panels are the same data as the top panels, only here presented as an orthogonal vector pair in the North and East directions. The bottom panel shows when sunlight was on the payload.

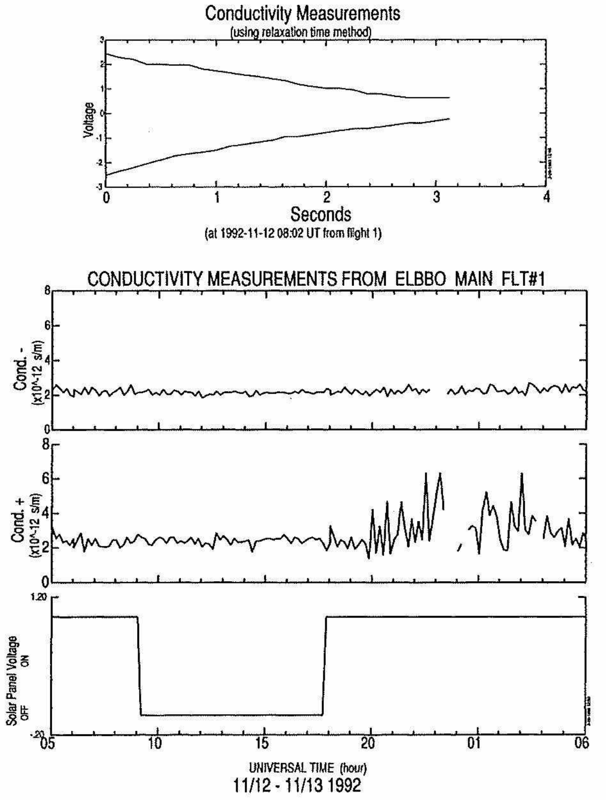


Fig. 5. Conductivity Measurements fro ELBBO4. The top plot shows the decay curves from the positive and negative relaxation profiles of a particular measurement. The bottom plot presents the negative ion (top) and positive ion (centre) conductivity. The bottom panel is the solar panel voltage as in Figure 4.

almost 90°. Not shown on this map are the locations of ground reception stations for the HF telemetry at Dunedin, NZ; Perth, Australia; Durban, RSA; Port Stanley, Falkland Is; and Amundsen-Scott South Pole Station; and of ground reception of Trimpis at Dunedin (including two other sites nearby), Durban and at Faraday, Antarctic. The location of the launch site (Dunedin) is recognisable as the source of the trajectories.

Figure 1 is a series of plots showing the four long duration ELBBOs. Note that the flight numbers do not correspond to the order of launch. All balloons underwent a counter clockwise (CCW) or generally westward motion around the southern hemisphere until mid February when ELBBO 2 reversed to clockwise (CW) motion. During the first few weeks after launch in November the first two ELBBOs launched circled CCW around in a pattern centred on a point south east of New Zealand half the way down to Antarctica. All of the ELBBOs encountered the coastal regions of Antarctica at latitudes below 70 degrees south. Shortly after changing to CW motion, ELBBO 2 took a "short cut" almost directly over the South Pole (see Figure 1) making a traverse across the long axis of Antarctica in about one week. This means that Polar air at 25 km altitude can (at least sometimes) exchange with sub-Antarctic air in a matter of days.

Figure 2 presents an example of the types of separation distances we have seen. The three symbols refer to separation distances between 4&5 (x), 4&6 (o) and 5&6 (*). Several studies required global separations of the ELBBOs from one another (and from ground stations for the Otago studies) ranging from small to large which were served well as indicated by this figure.

In Figure 3 we show the times for which we have data via the satellite ARGOS system. Most of the data gaps are related to times when there are data gaps greater than 6 hours. This is principally due simply to power system problems wherein the battery could not supply enough energy to last the whole night. In every case the battery happily charged up again once the solar panel became sunlit again the next morning. Because of the large separations indicated in Figures 1 and 2, these late night dropouts usually do not correspond to the same times on different balloons. Figure 3 does not include the data received via the HF telemetry. HF transmission from the ELBBOs was restricted to daylight hours to conserve battery charge during the night, so data held on RAM during the night were transmitted then. The HF reception stations, have closed down reception (the last ELBBO is no longer transmitting HF), are have sent the recorded data to Dunedin for processing.

Science Data Discussion. One of the most exciting initial discoveries in these data is shown in the next figure (Figure 4). Here we present the Horizontal Electric Field from one payload for a day, including all the data including occasional telemetry glitches. It was reported from earlier work [1] that,

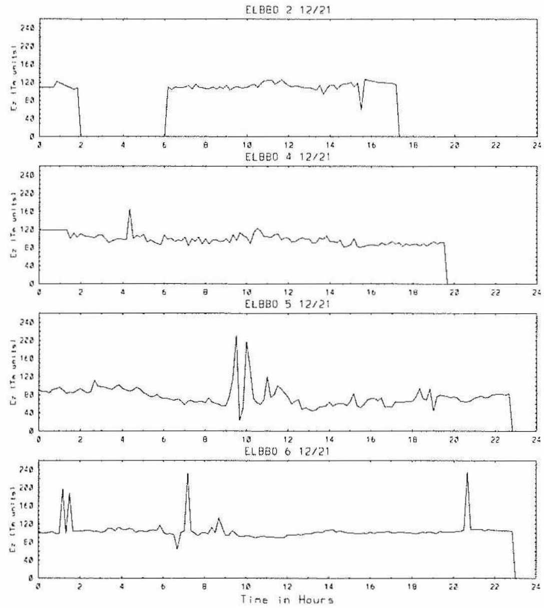
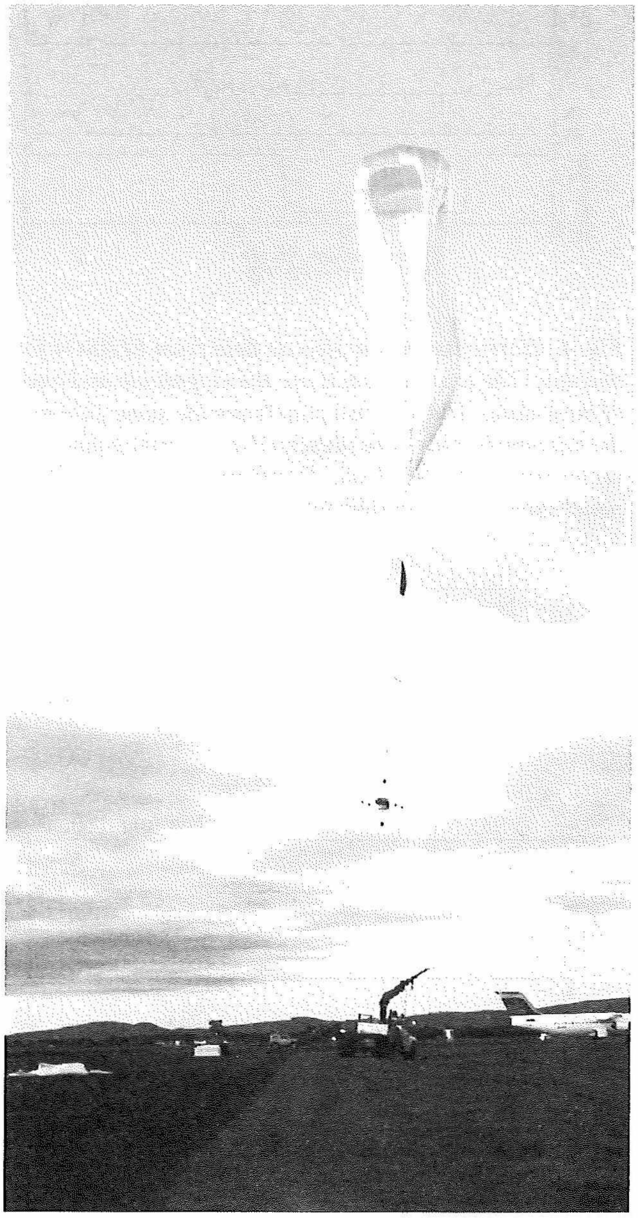


Fig. 6. Example of the vertical electric field from 4payloads simultaneously for 24 hours. Spikes in the bottom two panels are data transmission errors; spikes in the top panel may be real. The times of no data in the top two panels correspond to times of power system problems of the first two payloads. Each payload has a slightly different zero level but they each tend to be near the centre of each panel. This then indicated that the average electric field is negative (downward pointing) as expected for fair weather electric fields.

unlike previously thought, there is another source for electric fields in fair weather. This "new source" was characterised by a continual counter clockwise (CCW) rotation (in the southern hemisphere) of the vector field and by magnitude variations between day and night by a factor of 2 to 10. There had been no confirmation of these earlier studies until now. In this Figure 4 one can see clearly that the field rotates (see the second panel from the top) with a period in this case of about 14 to 16 hours, as expected for an inertial gravity wave at this latitude. The straight line is just to help identify this rotation in these data which also show short term perturbations — presumably related to local events. The bottom panel shows when it is night time at the payload, and this time corresponds to quiescent field times, just as shown in the earlier work. At this time, there is no clear theory as to how the field might couple to gravity wave motion.

Similarly to the electric field, the conductivity data are of high quality. Figure 5 shows an individual bias sweep (top plot) showing how clean these profiles are, and a day long period of the positive and negative conductivity. As in previous balloon payloads the negative ion conductivity (top panel, lower plot) is stable day and night while the positive conductivity shows the disturbing presence of photoemission in the vicinity of the payload. This photoemission has been modelled by *Byrne et al* [2] and can be removed from the data (see [3]). Again as for the previous figure, this plot includes all the data and shows how clean the data are. Therefore, the conductivity data are also of high quality and may be directly used to calculate the current density as a product with the electric field.

As an example of data from multiple ELBBOs simultane-



ELBBO 3 immediately after launch at about 5 a.m. local meridian time from Dunedin Airport taxiway. At this altitude the balloon is only 2% full of helium. The balloon "train" (balloon, parachute and radar reflector) is laid out downwind. The payload (gondola) is suspended on the crane mounted on the truck seen which attempted to be under the balloon at the moment of gondola release. Much calmer conditions prevailed for most of the launches. Note the six electric probes (one pair for each axis) which appear as black dots about the gondola.

ously we present Figure 6 which is a plot of the vertical electric field (Ez) from four payloads. These data are still in telemetry units (TM units) where the zero level for each payload is different, but approximately in the centre of each panel. Clearly the direction of the fields are similar — downward pointing or negative relative to the zero — as expected for fair weather electric fields. The average value if converted to electric field units for these data would be approximately 0.5 V/m downward in general agreement with earlier results.

Phase and amplitude perturbations ("Trimpis") in high power VLF transmissions have not previously been monitored from such balloons before. These perturbations are produced by short-lived (~30 seconds) ionisation anomalies [4]. The anomalies are produced by energetic electrons precipitated from the Radiation Belts through amplification of whistlers from lightning.

The Trimpi shown in Figure 7 was observed on Flight 5 (ELBBO 6) near Tasmania (see bottom right, Figure 1). The sign and relative magnitude of the perturbations, in this case a relatively rare combination of negative phase and positive amplitude perturbations (the Trimpi observed simultaneously on the ground at Dunedin was +ve phase, +ve amplitude), and the way these vary with longitude for each of the VLF transmitter monitored (NWC, Western Australia; NAA, Maine, USA; and NPM, Hawaii) will help determine the role of VLF waveguide modal interference [5], the geographical shape [6] of the ionisation anomalies (elongated E-W?), longitudinal effects and possible effects of high power VLF transmissions on the Radiation Belts, as previously indicated from hiss observations [7] made in the "EMA" balloon series of 1983-84 .

The INPE X-ray measurements will also show up such energetic electron precipitation when it occurred in the vicinity of the ELBBOs.

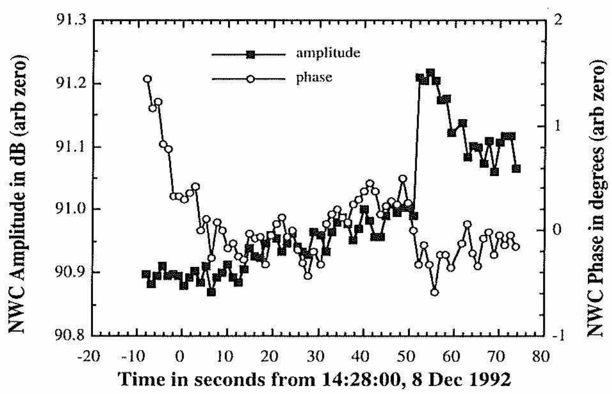


Fig. 7. Perturbation ("Trimpi") of the VLF (19.8 kHz) signal from transmitter NWC (North West Cape seen on the extreme CCW edge of Australia as viewed in Figure 1 maps) observed in phase (open circles) and amplitude (black squares) on board ELBBO 6 slightly west and south of Tasmania.

Acknowledgments. We wish to thank the NSBF (National Scientific Balloon Facility) and in particular the payload manager Erich Klein and his field staff for helping make these flights possible. In addition the work of many individuals not part of the science teams from the US Antarctic Program of the NSF, NASA Wallops Flight Facility of Goddard, Physical Science Labs, NMSU, Space Science Labs of the University of Washington, INPE, Brazil and the Physics Department of the University of Otago, New Zealand were instrumental in the success of the ELBBO program. A note of special thanks to: Ben Barnum, Yaqi Li, John Chin and Jeff Ross of the University of Washington; Dave Hardisty, Peter Stroud, Peter Bruce and Myles Thayer of the University of Otago; and to O. Pontiere and W. Kabata of INPE, for engineering and programming help.

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Electromagnetic Waves

An URSI Conference Report from *Physics Today*, July 1960

Although the wave equations of Maxwell's theory have been studied for about a hundred years (or two hundred, if one includes the special cases which also arise for the vibrating strings and pipes treated by Daniel Bernoulli, D'Alembert, Euler, and Lagrange), the subject is far from closed. Emphasis and interests have shifted in the course of time, but the spectrum of activities has remained about the same. Some individuals are concerned with electromagnetics per se, and deal primarily with problems relating to the generation, transmission, and reception of electromagnetic radiation; others are interested in mathematical aspects of the initial value and boundary value problems of the equations; still others take wave physics in general as their field, and regard electromagnetics as one discipline for which the phenomena may be relatively directly associated with theory.

This subject overlaps the domains of several professional societies, each of which makes little provision for "outsiders" working on "its" problems. However, there exists a broad professional framework in electromagnetics within which research physicists, mathematicians, and engineers, independently of their nominal labels, may gather to discuss problems of mutual interest: the International Scientific Radio Union (URSI). In addition to its triennial International General Assemblies and semiannual national meetings, URSI sponsors symposia on relatively broad topics in its field. In particular, the International Symposium on Electromagnetic Wave Theory held June 15-20, 1959, in Toronto, jointly sponsored by Commission VI of URSI and the University of Toronto, was the third of a series; the previous ones were held at McGill University in 1953, and at the University of Michigan in 1955.

The Toronto meeting was opened by its chairman, G. Sinclair. S. Silver gave the welcoming address in which he mentioned several central problems of the symposium: There exist no explicit forms connecting high- and low-frequency approximations for scattering problems. Multiple scattering solutions for general statistical distributions are required to extend results obtained for the gaslike and periodic limits. Surface wave treatments must determine whether or not a particular approximation overemphasises a physically insignificant aspect of a problem. New techniques are required to treat antennas from a data-processing point of view. In closing, Silver discussed the roles of scattering and antennas in connection with systems of earth satellites for long-range communications.

The formal program, covering five and a half days, consisted of sixty-five nonconcurrent papers (and two panel discussions) dealing generally with scattering, surface waves, and antennas. All sessions were held in the large lecture hall of the McLennan Laboratory (Physics Building), which easily accommodated the 250 or so participants from Asia, Canada, Europe, and the United States. Since the broadness of the symposium's program precludes a comprehensive review, this report merely sketches background general topics, and mentions some recent developments presented in Toronto.

Practically all of the papers dealt with boundary value problems of the wave equations, and most of these were scattering problems in a general sense. In order to predict how the radiation produced by a source is redistributed by obstacles, one requires a solution of appropriate wave equations, subject to prescribed boundary conditions at the objects, and subject to conditions at large distances from the region containing the objects. The differential equations describe local properties of the media in question; the boundary conditions take account of the physical characteristics, shapes and sizes of the obstacles; and the conditions at infinity specify the forms of both incident and scattered components of the solution. One may be interested in the field arising from a particular object, or collection, or in the average field and energy flux to be expected for some statistical distribution of objects.

As is well known, the vector form of Green's theorem provides a representation for the scattered wave as a surface integral (the rigorous embodiment of Huygens principle); were the values of certain field components (or, equivalently, the surface charges and currents) known on the obstacle, then the field in space would follow on integration. However, in general, the required surface values are specified by unsolvable integral equations. In a few special cases, for which the surface of a homogeneous scatterer coincides with one or more complete coordinate surfaces in one of the systems in which the wave equations are separable, solutions are obtained as infinite series of more or less tabulated special functions. Simple closed-form solutions in terms of elementary functions are rarer still. However, through analytical approximations valid for restricted values of the parameters, and through heuristic procedures motivated by the insight obtained in more elementary problems, one can now obtain explicit results which are adequate to describe many principal phenomena. The somewhat pathological separable problems play a unique role in this subject: on the one hand the surface fields on planes, cylinders, wedges, spheres, etc., provide high-frequency approximations for the local fields on more complicated scatterers; on the other, general analytic or heuristic procedures for more complex scatterers may be tested "experimentally" by specialising them to the separable problems and checking numerically.

Starting at the high-frequency end of the spectrum, with homogeneous scatterers having regular surfaces and radii of curvature large compared to wavelength, one may use geometrical optics as a first approximation. Except for shadow regions and caustics, this procedure gives the correct leading term of the asymptotic expansion of the exact solution. Aside from elementary geometrical considerations and the rules of specular reflection and energy conservation, it hinges essentially on using the Fresnel reflection coefficients to describe the local field at the interface. These coefficients, obtained from the separable problems of a plane wave incident on a plane boundary, may also be used to approximate the unknown surface components in the rigorous surface-integral representation for the scattered field. Thus for a large perfect conductor, one may take the relevant surface field components as twice the incident values on the "illuminated" side of the scatterer, and zero on the other and approximate the field in space in terms of Fresnel integrals (or Airy integrals, etc., if there are caustics and focuses). Although such "physical optics" results are in general only qualitatively correct, they are adequate for many practical purposes at high frequencies.

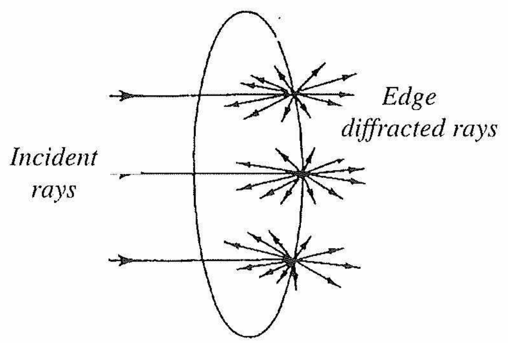
The assumption that the surface field on perfect conductors falls discontinuously to zero at the boundary of the illuminated portion is but a limiting short wave approximation. This was generalised by Fock, who replaced the surface field near the "shadow line" by that on a simpler scatterer (parabolic cylinder, or paraboloid) having the same local curvature. The Fock fields fall smoothly on the shadow side, and an intuitive picture of their decay may be obtained from their asymptotic values at distances from the shadow boundary large compared to wavelength: these "creeping waves" fall off exponentially because of radiation losses. As brought out in the Toronto panel discussion on scattering, Franz originally sought such waves in the separable solution for the perfectly conducting circular cylinder (for polarisation perpendicular to the axis) in order to account for the series of almost evenly spaced extrema in plots of the measured back scattered intensity versus the ratio of radius to wavelength; the spacing of these extrema suggested an interference effect between a wave specularly reflected from the lit part of the cylinder, and waves which had "crept" around its shadow side. At the 1953 Electromagnetic Wave Theory Symposium, Franz and Deppermann used an asymptotic development of an integral equation to discuss creeping waves on perfect conductors; and at the 1955 Symposium, Franz and Beckmann, Keller, and van de Hulst considered the more complex surface fields on homogeneous dielectric scatterers. In 1955, Keller gave the leading effects of variable surface curvature on the damping of such surface waves; in Toronto, Franz and Klante, and Keller discussed additional terms. In the few years since these and analogous new extensions of the high frequency range were introduced, Fock, Franz, Keller, Siegel, and their associates have applied them to dozens of special problems; current applications were indicated in papers by Goodrich, and by Kazarinoff and Ritt.

Dropping the requirement that all radii of curvature of a scatterer be large compared to wavelength, the local field on an infinite cylinder of arbitrary radius may be used either in the surface-integral representation, or directly, to construct approximations for the field scattered by a finite cylinder. Similarly a finite scatterer with a sharp edge may be treated by exploiting Sommerfeld's and Macdonald's solution for the field on the semi-infinite wedge. An infinite cylinder having a triangular cross section with sides large compared to wavelength may be regarded as a collection of three "infinite-wedge edges" (plus specularly reflecting planes). As a first approximation, each of the three edges may be treated as excited solely by the plane wave; then the "coupling effects" of the "single scattered edge waves" on each other may be developed in terms of higher-order scattering processes (by regarding each edge as excited by the asymptotic forms of the waves leaving the other two in response to the primary excitation, etc.). More directly, the infinite wedge result may be used in a self-consistent procedure which treats each edge of the finite wedge as excited by the incident wave and by two cylindrical edge waves of initially unknown amplitude. The solution for the degenerate case of the wedge of zero angle (i.e., the half-plane) was first used by Schwarzschild to construct the series solution and a single scattering approximation for a wide aperture in an infinite plane screen, and higher-order scattering of the edge waves was recently treated by Karp and Russek. Keller, and Clemmow. Similarly Braunbek, Clemmow, Keller, and Levine treated the wide circular aperture (and disk) by assuming that the edge field was approximately that on a straight edge (half-plane) locally coincident with the edge of the aperture; and in Toronto, Braunbek compared diffraction by funnel-shaped screens with their planar limit (the circular aperture).

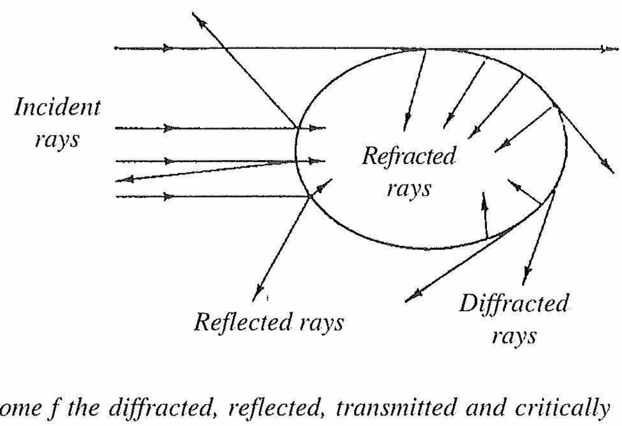
The infinite-wedge result was also used by Siegel to approximate the local field on the curved edge of the base of a finite cone, and Keller took into account higher-order scattering; for this case, the tip contribution is gotten from treatments of the separable problem of the semi-infinite cone by Macdonald, Hansen and Schiff, Felsen, Silver, and others. Open areas for edged and tipped finite scatterers hinge on the unknown solutions for semi-infinite dielectric wedges and cones. Papers by Felsen, Karp and Karal, and Shmoys dealt with the related problems of wedges and cones having constant and variable surface impedances.

With reference to the planar obstacles mentioned above, it may be recalled that the separable series solution for the strip in terms of Mathieu functions was considered by Morse and Rubenstein, and that similarly Meixner and Andrejewski treated the disk in terms of oblate spheroidal functions. However, although these representations are being used for numerical evaluations and asymptotic developments (as are the analogous Bessel function series for the circular cylinder and sphere obtained by Rayleigh and Mie), emphasis has shifted largely to the more general forms and procedures. Thus numerical computations with the series solutions have been used more to test the explicit asymptotic representations (obtained by variational methods, transform methods, ray methods, etc.) than for comparison with measurements. Much of the present effort on arbitrary edged obstacles is reminiscent of work on curved surfaces some years ago: using straight-edge results to approximate fields on curved edges is analogous to using the fields on planes to describe local fields on curved surfaces. The next step is to base an approximation procedure on the simplest curved edge. For this reason as well as for its intrinsic interest, the circular aperture remains a prime target in the search for explicit approximations that can be generalised to more complicated curves; in particular, one seeks to isolate curvature corrections to straightedge fields appearing in the local field of the circular edge. The effects of such curvature dependent terms are indicated in recent papers by Levine and Wu, and Keller and Buchal; and analogous results may be sought by the integral equation procedures and transform methods used in the Toronto papers of Bazer and Brown, Clemmow, and Noble.

Edged scatterers may also be treated directly by recent extensions of geometrical techniques initiated by Luneburg's systematic use of rays for field problems, and by his demonstration that geometrical optics gave the correct leading term in an asymptotic expansion at high frequencies. Thus Keller deduces "diffraction coefficients" for "edge-diffracted rays" and "vertex diffracted rays" from the known asymptotic



A plane wave normally incident on a disk.



Some f the diffracted, reflected, transmitted and critically refracted rays produced when plane wave hits convex cylinder of lower light velocity than the surrounding medium.

forms of the solutions of the semi-infinite wedge and cone. These coefficients play essentially the same role in describing diffraction from finite edged and tipped scatterers, as do the Fresnel reflection coefficients in describing specular reflection from finite surfaces. For example, a ray incident normally on an edge gives rise to a "fan" of rays normal to the edge (the rays being the radii of the corresponding cylindrical wave); and a plane wave normally incident on a planar obstacle gives rise to a family of such fans, each perpendicular to a point on the rim. For a plane wave normally incident on a circular disk, there are only two rays (from diametrically opposite points) diffracted to an off-axis point, but an infinite number (from the complete circumference) reach an observation point on the axis. Consequently the field in the geometrical shadow may be interpreted in terms of edge-diffracted rays, and the "Poisson" bright spot along the axis is simply their caustic. Similarly the more complex bright curves observed by Coulson and Becknell in the shadows of elliptic and parabolic plates are also caustics of edge rays: for normal incidence, the caustic surface of the rays singly diffracted from the edge of an arbitrary planar object is a cylinder whose generator is normal to the obstacle and whose cross section is the evolute of the rim. In addition, the effects of multiple diffracted rays have been taken into account in various applications. (Of course, the concept of diffraction as an edge effect goes back to Young; also the Maggi transformation reduces Kirchhoff's surface-integral for the field of an aperture to a line integral around its edge, and Rubinowicz's treatment shows that the stationary points of the line integral equal the seats of the "edge-diffracted rays". But Keller's ray procedure requires no integration, and leads to better values.)

Similarly, analogous to the creeping waves, a ray incident tangentially on a scatterer injects a "surface ray" (as well as giving rise to space rays in all directions) and this ray running around the surface and through the shadow side continuously sheds rays and part of its energy tangentially. The path from source point to observation point via the scatterer's surface (two straight lines tangent to the scatterer joined by a curve on its surface) is a "true ray" in the sense that it makes Fermat's integral stationary among all curves lying partly on the surface.

In addition to rays specularly reflected at discontinuity surfaces of the physical parameters, there are higher-order reflected rays arising from all surfaces along which the derivatives of the parameters are discontinuous. Similarly, lines of discontinuity of any derivatives of surfaces act like edges, and discontinuities in any derivatives of edges or of isolated points of surfaces act as vortices.

Turning to the low-frequency region, where the incident wavelength is large compared to all dimensions of the body, one can obtain approximations by perturbing around the solutions of the corresponding potential problems. Thus by specialising the surface integrals for the scattered field to scatterers small compared to wavelength and distance of observation correspondingly large, Rayleigh showed that the reduced integrals were proportional to those of the related potential problems. Rayleigh obtained the leading terms for elliptic cylinders and ellipsoids, including the limiting strips and disks (and apertures); and these values of the scattered fields, which include up to the second power of the frequency, define the "Rayleigh scattering" range. Since then, a number of relatively general procedures yielding low-frequency approximations for various homogeneous scatterers have been used by Bethe, Copson, Levine and Schwinger, Tai, and others. In particular, the most complete explicit results for the strip and circular disk were derived by Bouwkamp, and by Bazer and Brown. In 1953 Stevenson extended Rayleigh's procedure to obtain additional terms for the ellipsoid; but more general shapes lead to complicated potential integrals difficult to evaluate, and alternative approaches are being sought. In their Toronto paper, Siegel and Senior discussed algebraic procedures for treating nonsymmetrical bodies, and pointed up the need for explicit results between the low and high-frequency ranges.

In the panel discussion on scattering, Siegel also stressed the lack of transition forms between high- and low-frequency representations, and raised this topic for general consideration. There was some agreement that existing high-frequency procedures could be extended down to scatterer dimensions of the order of the wavelength. The remaining range may then be treated directly for the separable problems of the wave equations, and perturbation procedures practically suffice to close the range for scatterers whose potential equation problem is separable. However, in general, the range where the scatterer's size lies between, say, a tenth of the wavelength and the wavelength, lacks explicit representations.

Another general class of scattering problems is that of an inhomogeneous object whose dielectric constant or scattering potential is close to unity, and whose internal "optical path difference" is small. For this case, one usually represents the scattered field as a volume integral whose kernel involves the free-space Green's function (the field of a monopole or dipole), the scattering potential, and the internal field at a point in the scattering region; were the internal field known (i.e., could one solve the integral equation obtained by picking an observation point within the scatterer), then the field elsewhere would follow on integration. The Rayleigh-Born approximation replaces the internal field by the incident wave, and thereby treats the object as a distribution of elementary sources each excited solely by the incident wave. The results were improved by van de Hulst, Glauber, Montroll, Saxon, and others, who approximated the local internal field by a straight "ray" taking account of the phase difference an incident ray acquired in penetrating to a particular point in the scattering region (essentially a Wentzel-Kramers-Brillouin approximation for the phase) .

More recently, instead of working with the usual free space Green's function, Saxon obtained representations for the scattered field in terms of a more complicated Green's function having the correct local behaviour—one describing propagation along a curved geometrical path with appropriate wave number. This exact integral equation then yields the corresponding WKB value as the initial approximation, and higher order corrections (depending on the variation of the wave number along a ray and on the curvature of the ray) can be obtained in principle. However, it is simpler to work with an alternative exact integral equation in terms of a straight-ray local Green's function (analogous to the straight-ray local field in the conventional volume integral representation). Similar forms were obtained by Schiff using an iterative procedure taking account of multiple scattering by the elementary sources in the usual free-space Green's function representation, and Saxon and Schiff jointly considered several quantum-mechanical scalar scattering problems. In Toronto, Saxon treated the vector electromagnetic case, and made the effects of polarisation explicit.

Direct high-frequency approximations for inhomogeneous scattering regions may in general be obtained by conventional geometrical optics procedures, provided that no caustics or shadows occur. However, such discontinuities arise even in unbounded media in which the dielectric constant (or scattering potential) and all its derivatives are continuous. The caustics may be treated by exploiting solutions of problems yielding explicit results for analogous envelopes of rays. For this purpose, Debye first treated caustics of circular and spherical wavefronts, and Picht and Luneburg generalised his formalism to arbitrary wavefronts in scalar and vector problems, respectively. Keller and Kay have obtained explicit approximations for the field near caustics arising in special problems (e.g., the reflection of a plane wave from a segment of a parabolic cylinder); and Kay's Toronto paper, based on Picht's solution of the wave equation as an integral of plane waves over a caustic, gave expressions near a general caustic in terms of the geometry of the problem. As for the shadows Keller obtains the leading terms by using "imaginary rays"—rays whose complex phase functions, satisfying the eiconal equation, provide the analytic continuation from a lit region into the shadow (analogous to fields penetrating forbidden regions via the tunnel effect of quantum mechanics). In their Toronto paper, Keller and Levy used such rays to treat scattering by a sphere with a radially varying index of refraction.

The remarks on Schiff's multiple scattering approach to the Green's function of an inhomogeneous medium, and on multiple scattering by the three edges of the triangular cylinder, lead into another of the problem areas sketched by Silver in his opening talk: Treatments of general distributions of scatterers are required to bridge those for sparse random distributions and periodic arrays. The total average intensity for the more general case would depend critically on the ratio of the average volume available per scatterer centre to its minimum value say, on L, the relative "elbow room". Visualising the distribution as a "rare gas" for large values of L, then decreasing L corresponds to "compressing" the distribution through its dense gas and liquid state analogues: for $L \rightarrow 1$, the "local order" increases and the field should reduce to that of an appropriate crystal; at the other limit, $L \rightarrow \infty$, the local order disappears and the results should reduce to those of the analogous ideal gas.

Although there exist no explicit representations for the probability functions required to treat general three-dimensional distributions over their full range of L, the infinite "one-dimensional liquid" of identical elastic objects is relatively amenable to analysis. Thus Zernike and Prins took the one-particle distribution to be constant, and used probability consideration to derive a pair distribution function in terms of L (here the ratio of average to minimum separation of scatterer centres—a minimum generally greater than a scatterer's width). They obtained a single scattering approximation for a large number of scatterers on a line, and showed numerically that for $L \rightarrow 1$, both pair-function and intensity became sharply peaked, and that for $L >> 1$, both became relatively smooth. More generally, by using the one-dimensional distribution to treat coplanar, parallel, arbitrary cylinders, one obtains a model for a relatively "random screen"; imaging the results for scatterers symmetrical to the plane of the distribution yields corresponding functions for the analogous "rough surface" of protuberances on a ground plane. Also, one can take into account multiple scattering effects which are significant for near-grazing incidence, for closed-packed small scatterers, and for resonances in the near-periodic limit (relevant to the grating anomalies of Wood and Strong) .

Thus Twersky's paper considered multiple scattering of plane waves by arbitrary cylinders whose ensemble was specified by a Poisson one-particle distribution function, and by a more convergent transform of the pair-function introduced by Zernike and Prins. Representing the field of one configuration as a sum of surface integrals, and averaging over the distribution, gave an integral relation between the average fields with one and two particles held fixed; equating these to each other led to an integral equation involving the known distribution functions and the presumably known scattering amplitude of an isolated cylinder. The absolute square of the average field specified the "coherent intensity", and a corresponding approximation was constructed for the "incoherent" differential scattering cross section. For $L \rightarrow 1$, the total average intensity reduced to that for the general diffraction grating of periodically spaced elements; at this "crystalline" limit, the field was all coherent and consisted of the usual transmitted and reflected propagating spectral orders plus the infinite set of evanescent surface waves; their amplitudes were specified in terms of their single scattered values by means of a functional equation whose operator equalled an integral minus the analogous sum (a relatively rapidly convergent representation). For $L \rightarrow \infty$, the "ideal gas" limit, the coherent field consisted of the directly transmitted and specularly reflected plane waves, and the differential cross section was relatively smoothly varying; solving two algebraic equations gave all amplitudes explicitly in terms of their single scattered values. The coherent field for the "liquid" had the same form as for the gas, but the incoherent intensity was peaked in the vicinity of angles corresponding to the non central spectral orders of the grating.

The above illustrates one of two general procedures for treating such problems. Alternatively, instead of regarding the cylinders as individual scatterers, one may consider them as perturbations of an otherwise uniform region; then, the Fourier series or Fourier integral components of the spectral representation of some appropriate parameter of the region may be taken as the "scatterers". Thus to analyse the perfectly conducting reflection grating, Rayleigh, Artmann, and Lippmann represented its periodic profile as a Fourier series, and obtained an inhomogeneous set of linear algebraic equations for the Fourier amplitudes of the field in terms of those of the profile. Similarly Rice, and Ament, used essentially an analogous procedure involving Fourier integrals to treat a randomly perturbed planar surface. As for volume distributions, Laue analysed the scattering of x rays by crystals by means of an algebraic set of equations for the Fourier amplitude of the field in terms of those of the periodic index of refraction. Similarly, in Toronto, Hoffman treated an index which was a slowly varying random function of position, and obtained an inhomogeneous integral equation for the continuous Fourier amplitude of the field in terms of that of the index. Expanding the result as a series (by a Neumann iteration starting with the field in an unperturbed medium), Hoffman investigated conditions on the form of the index that insured mean-square convergence.

The perturbation approach has its roots in Rayleigh's work on the effects of inhomogeneities of a medium on the coherent field; the associated incoherent scattering was treated by Pekeris, Debye, Booker and Gordon, Silverman, and many others in terms of the autocorrelation of the values of the index at two different points. The alternative approach, which considers volume distributions of distinct scatterers (and which also stems from Rayleigh's treatment of the blue colour of the sky), was used by Ewald for a lattice of dipoles; and by Reiche, Yvon, Kirkwood, Foldy, Lax, Mazur, Twersky, and others for random distributions. Foldy's self-consistent treatment of monopoles was generalised essentially three ways to obtain the propagation coefficient, say K, of the coherent field for a random distribution of relatively arbitrary scatterers excited by a wave having propagation coefficient k. Each procedure expressed K in terms of an isolated object's scattering amplitude, say f: but one used $f(k \rightarrow k)$, the amplitude of the object in free space; another used $f(K \rightarrow K)$, the amplitude in the new medium associated with the coherent field (Lax); and the third used $f(K \rightarrow k)$, the amplitude of an object excited in K-space but radiating into k-space (Twersky) . The function f $(K \rightarrow k)$ corresponds to the amplitude for a new class of single-body scattering problems in which the source and radiated terms of the solution satisfy different wave equations. This type of scatterer may be more palatable if its limiting form for a monopole is recognised in the usual volume integral representation for the field scattered by a constant potential $k^2—K^2$, i.e., in the integral whose kernel comprises a monopole (the free k-space Green's function) weighted by the local field: since the local field travels in K-space, these monopoles radiating into k-space are elementary forms of the "schizoid scatterer" characterised by $f(K \rightarrow k)$.

One class of scattering problems treated in Toronto served to link the "scattering" sessions with those on "surface waves": problems dealing with point and line sources exciting the interface of two dielectric half-spaces appeared in both sets of sessions and the second set also dealt with eigenfunction problems of the fields that could be supported on various interfaces. Schelkunoff, who opened these sessions, mentioned Rayleigh's original work, and cited an additional dozen or so "surface waves".

One may define a "surface wave" as a wave propagating along an interface and exponentially damped normal to it. If the wave is also damped in travelling along the interface, either because of heat losses in one or both media, or because of radiation losses associated with a curved or irregular interface, then this should be relatively small compared to the damping at right angles. The simplest example of such waves arises in total reflection of a plane wave at a plane interface of two dielectrics: here the transmitted wave in the medium of lower index falls off exponentially normal to the interface, but propagates along it without damping. Analogous cylindrical waves may propagate axially on the interface of an infinite circular cylinder in an unbounded medium. and be damped radially; and cylindrical waves may also travel in a plane interface and be damped normal to it. Similarly the nonpropagating modes of the diffraction grating are surface waves attenuated normal to the plane of the cylinders, and creeping waves on curved scatterers are attenuated both normally and tangentially. (The above is merely one view; many others were represented in the panel discussion on surface waves.)

Today, surface waves are of particular interest in connection with microwave devices consisting essentially of a finite source (horn, slit, wire dipole, etc.) near a finite planar or cylindrical surface (dielectric clad metal, periodically corrugated. periodic impedance, etc.). The solutions for such problems are usually represented as a set of plane or cylindrical waves having real and complex directions of travel and a particular surface wave of the decomposition is singled out when its reflection coefficient has a pole singularity; however, whether such a term is numerically significant in the total field depends on the particular values of the parameters involved. For various structures ("highly reactive" boundaries) the surface waves appear to be the dominant terms, and the concept has proved fruitful for developing practical devices to guide energy ("external waveguides" such as the Goubau line, or pairs of wires) or for launching it (dielectric rod antennas, disk-loaded rods, and other "end fire" arrays).

Goubau's Toronto paper considered waves on plane or cylindrical interfaces of a lossy region, and developed a criterion for the transfer of energy from surface wave modes to the radiated field. Oliner and Hessel derived the propagation characteristics and field distributions of surface waves on a plain interface having a sinusoidally modulated surface reactance. They also considered the "leaky wave" solutions for this surface—a class of improper modes introduced for such problems by Marcuvitz, which although increasing exponentially with distance from the surface are quite useable for obtaining rapidly convergent field representations in limited angular regions (analogous to radioactive states). Barlow considered curved interfaces, and developed criteria for their efficiency as surface waveguides and radiators. Brown used the Wiener-Hopf technique to treat scattering of a surface wave by a discontinuity in the reactance of an interface. Papadopoulos considered scattering of a plane pulse by a conducting half-plane at the interface of two media.

Related papers dealt with finite sources near lossy interfaces. Friedman obtained a simple expression for magnetic line source excitation, and showed that at a particular distance from the source, the field near the interface had a maximum equalling roughly one and a half times the value for a perfect reflector. Gardner and Keller derived an explicit form for pulsed dipole excitation by a new method based on representing the spherical source as a superposition of cylindrical waves. Bremmer obtained multiple integral forms for continuous wave and pulsed dipoles; he represented the field as components propagated along continuous sets of trajectories from the source to the observation point the portions of the trajectories lying in the interface corresponding to surface wave propagation. Karbowiak treated a dipole between two parallel interfaces, and discussed the proper modes, quasimodes, surface waves, leaky waves, etc. Wait treated a dipole above a ground plane covered by a "gas distribution" of small hemispheres by substituting the appropriate plane wave reflection coefficient into Sommerfeld's integral representation, and using a saddle point approximation.

Additional papers dealt primarily with antenna problems: large radio telescopes based either on arrays of interferometers (Shakeshaft), or on stepped zone reflectors (di Francia); logarithmically periodic broadband structures (Rumsey), linear arrays (King), slot arrays (Knudsen) helical antennas (Kouyoumjian and Maclean), end-fire dipole arrays (Serracchioli and Levis), the near field of aperture antennas (Hansen and Bailin), etc.

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AN INTERPLANETARY, TYPE V RADIO BURST

The First Observation

Type V Radio Bursts are known to be frequency localised, relatively long lasting radio emissions related to Type III solar radio bursts originating in the solar corona at radio frequencies generally below 600 MHz. Type III radio bursts are excited by fast electron beams travelling across the solar corona outward into interplanetary space. The association of Type V bursts with Type III bursts therefore suggests that the latter are also generated by electrons from the Type III beam but that, owing to the localisation and much longer duration at a fixed frequency in Type V bursts than in Type III bursts, the source electrons must be scattered out of their path into some trapped orbit where they stay for a longer time able to generate escaping radiation. There have been several proposals to yield such a scattering when collisions become unimportant in the collisionless plasma of the solar corona. One possibility is that the electrons are scattered on electrostatic waves generated by themselves when possessing a nonvanishing gyroradius in the magnetic field of the streamer along which the Type III burst electrons propagate. But in all cases one requires a closed magnetic field configuration for keeping the scattered electrons trapped so as to let them radiate until they lose their energy or are lost by other processes such as pitch angle scattering.

This kind of radio burst is different from the so called U-bursts which may be used to map closed field configurations but which are nothing else but Type III burst electron beams which turn around when propagating along the closed loop magnetic field. In the case of Type V bursts, the main electron beam still remains on open field lines and escapes while only part of the beam may be scattered into a simultaneously present closed field configuration. Sometimes no scattering is invoked but simply velocity dispersion effects are made responsible for Type V bursts with the low speed electrons being responsible for the Type V, the fast ones forming the Type III.

In this case no closed field configuration would be necessary but the interpretation then causes problems with the acceleration mechanism at the site where the electron beam is injected. Also, if this would generally hold, one would expect to observe Type V bursts everywhere from the Sun out to interplanetary space. This is not the case. Under normal conditions Type V bursts have not been observed farther out in the corona than 2-3 Solar Radii which is a very strong argument for the requirement of closed field configurations.

Using AMPTE IRM observations between 0.1-5.6 MHz at 2 s time resolution we have discovered what we call the first Interplanetary Type V Radio Burst (R.A. Treumann and J. LaBelle, submitted for publication). IRM was a spacecraft of high ellipticity with apogee at 18.7 Earth radii. On Dec 21, 1984 between 0330-0430 UT it detected a faint solar/interplanetary Type III radio burst which below 1 MHz suddenly developed a rather intense band limited (about 300 kHz bandwidth), frequency localised, non-drifting emission. The event was clearly related to the Type III burst and, both in its time behaviour and in its spectrum, unrelated to simultaneously detected emission from Jupiter and some auroral kilometric radiation. The Type III burst was nearly unaffected and faded down into the low frequency region usually attributed to solar wind Type III radio burst conditions. We could rule out the possibility that the event had anything to do with harmonic or fundamental radiation from Type III or interaction with auroral kilometric radiation. We could also rule out the possibility that it was O-mode radiation. Hence the only reliable interpretation was that it was a Type V radio burst in interplanetary space far out of the solar corona. The use of the Type III emission which was clearly at the harmonic with no fundamental visible because of the faintness of the burst, yielded a density profile of the solar wind and positioning of the Type V between 12.6-15 Solar Radii.

Never have closed field configurations been observed at such distances and the would hardly be imaginable. We can, however, rule out the possibility that propagation effects due to beam dispersion could be responsible for the Type V, because its onset in frequency is extremely sudden. The type V does not evolve slowly out of the Type III which would otherwise be expected, because electrons would then have to propagate out to the site of the radiation and should manifest themselves in radiation at higher coronal frequencies as well. Hence our interpretation seems justified. What causes the emission could be, for instance, a toroidal field/plasmoid in the solar wind well outside the corona, some unknown magnetic interplanetary structure or, what would be the most interesting case, the corona-solar wind transition region itself. If this is some kind of discontinuity then one could under certain circumstances expect that an electron beam, or part of it, may change its properties non-adiabatically and evolve into a hollow beam with large transverse velocity components. Such a beam would emit beam-driven electromagnetic maser radiation as has been proposed in the literature for solar Type II shock radiation.

The most interesting point in this case would be the possibility of being able to map the solar wind-corona transition region by observing interplanetary Type V radio bursts. All other methods fail to do this. The only requirement is that the mother Type III burst must be faint enough not to obscure the Type V emission. Of course, and unfortunately, interplanetary Type III bursts are rather rare and, in most cases, strong because only the strongest and fastest Type III electron beams reach the solar wind.

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ACTIVITIES OF THE SWEDISH COMMITTEE

Within the Swedish National Committee of URSI (SNRV) there is a group named the **NRS Committee**, which has the aim of contributing to the development and the increase of radio technical competence.

The name NRS was taken in connection with the arrangement of two **N**ordic **R**adio **S**ymposia in Saltsjöbaden, Sweden, in 1986 and 1989. Today NRS stands not only for Nordic Radio Symposia but is a well-known symbol of activities in the radio field both within and outside the Nordic countries.

The very start of it was a discussion in the Swedish URSI Commission F on what can be done to activate the work of the Swedish URSI Committee, resulting in a proposal to organise an internordic conference or the like in the radioscientific field. That was in 1984. In my capacity as Chairman of the Swedish URSI Commission F I called a number of colleagues representing different spheres of radio activity. They supported the idea and assisted in the planning of the first Nordic Radio Symposium NRS 86.

Its title was *Aspects of Wave Propagation on Mobile Radio and Broad-Band Communications*. It turned out very well, and another one, NRS 89, followed. It dealt with Wave Propagation, Antennas and Systems. A third one, NRS 92, was organised in co-operation with the Aalborg University Centre, Aalborg, Denmark, under the title of Wave Propagation - Personal, Mobile and Satellite Communication.

In the beginning, the themes were connected to VLF, UHF and higher frequencies, but later there has been an expansion also to the HF region. Such an activity is the Nordic Shortwave Conference HF 92 on the island of Fårö in the Baltic sea.

In co-operation with the technical universities in Sweden the Committee has also held a number of NRS Seminars on special radio themes for a limited number of participants. Moreover, NRS Evening Meetings have been arranged on radio topics with invited guests.

A summary in tabular form is given below of the NRS programme. Further activities are being planned in co-operation with the universities and sponsored by industry, research establishments and administration.

Behind this internordic work lies an intention to gather the

NRS Symposia

NRS 86	Aspects of Wave Propagation on Mobile Radio and Broad-Band Communications	April 15-17, 1986 Saltsjöbaden, Sweden
NRS 89	Wave Propagation, Antennas and Systems	March 13-16, 1989 Saltsjöbaden, Sweden
NRS 92	Wave Propagation - Personal, Mobile and Satellite Communication	June 1-4, 1992 Aalborg University, Denmark
HF 92	Nordic Shortwave Conference	Aug. 10-14, 1992 Fårö, Sweden
NRS 95	To be decided	
HF 95	Nordic shortwave Conference	August, 1995 Fårö, Sweden

NRS Seminars

Multipath Propagation and Channel Models	June 6-7, 1990 Lund University, Sweden
Area Communication Systems - ensuring Capacity and Reliability	June 3-4, 1991 Royal Institute of Technology, Kista, Sweden
Signal Processing in Radio Equipment-Digital and Analog Implementation and Development of Algorithms	April 2-3, 1992 Luleå University, Sweden
Microwave Systems of Tomorrow - Visions and Realisation	November 18-20, 1992 Chalmers University of Technology, Göteborg, Sweden

ACTIVITIES OF THE SWEDISH COMMITTEE

NRS Evening Meetings

Future Radio	May 14, 1991 Swedish Defence Material Administration, Stockholm, Sweden
Research, Development and Education in the Field of Radio	December 3, 1991 Ericsson Radio Systems, Stockholm, Sweden
Future Radio (cont. of discussion in May 1991)	May 19, 1992 Swedish Telecom, Radio Haninge, Sweden

knowledge and the people engaged in it in the Nordic countries: Denmark, Finland, Norway and Sweden. The intention is to make the co-operation mote efficient, effective and stronger. By initiatives like NMT, Nordic Mobile Telephone, the Nordic countries have been more or less pioneers. It is desirable and important to keep such a position and to strengthen it.

NRS is thus a forum for contacts and interchange of information between experts, scientists, technicians and people engaged in development. The NRS Committee works for exchange of knowledge between different disciplines and between university and the radio industry etc.

The members of the NRS Committee represent the Swedish National Committee of URSI, the telecommunication operators, the radio industry, the defence and universities.

Åke Blomquist
Chairman of NRS Committee

URSI President, Edward Jull, and author and Chairman of the NRS Committee (also Commission F Official Member of the Swedish Member Committee of URSI),Åke Blomquist, during a meeting in Sweden in 1992.

SEQUENTIAL SPORADIC E

ABSTRACT—Sporadic E layers are frequently observed to descend from a height around 150km down to the E region. This descent can take several hours. This type of sporadic E is called sequential sporadic E, among other names, and its gross features can be determined using scaled data from a conventional ionosonde. In this note, some of the features of sequential sporadic E are discussed, together with potential areas where useful research is possible. This phenomenon may provide new insights into the processes producing some mid-latitude sporadic E.

1. Introduction

The term "sporadic E" is used for a wide range of ionospheric E-region perturbations seen on ionograms and encompasses particle precipitation, plasma instability and dynamic processes extending from the pole to the equator. While different physical processes are recognised, empirically based statistical models (e.g., Smith 1957, Leighton et al. 1962) have rarely been able to discriminate between them, thereby confusing the macro and micro scale structures. This deficiency arises, in part, because the global data set comes solely from ionogram analysis where it is difficult to devise unambiguous rules for discriminating between different physical processes. In this note, one particular type of sporadic E, sequential sporadic E, is described.

There is a long history of sporadic E being described as a descending layer and explained in terms of atmospheric tides. Descending sporadic E layers are frequently observed on ionograms from some mid latitude locations. One of the earliest reported observations (McNichol and Gipps, 1951) recognised the semidiurnal nature of sequential Es and suggested this explained the two maxima seen in sporadic E occurrence. They described sequential Es as a layer that formed above the E region, sometimes higher than 150km, and descended into the E region where it dissipated. They called this type of sporadic E, sequential Es, or Ess. They propose that sporadic E is divided into two classes, one of which was sequential Es, or Ess. The McNichol and Gipps paper outlines all the important properties of sequential sporadic E. Their general points are outlined here.

- The layer starts in the F1 region and descends first as E2,
- normally it appears after sunrise, with a second less prominent appearance after noon,
- it is a strong blanketing layer (the morning layer may blanket the E/F region preventing the afternoon layer from being seen).
- As the layer descends, foEs increases and there is evidence of the layer thinning (the high frequency retardation part of E2 disappears),
- as it reaches 110-100km the layer becomes patchy and breaks up.
- Often two descending sequences of Es are seen, one in the morning and the second in the afternoon. These descending sequences may explain the double peaked sporadic E occurrence statistics.
- The layer lifetime depends on season, being most important in summer, although it is still present in winter when Ess is seen one day in four,
- when two sequences occur in a day, the second sequence has a lower reflection coefficient (fbEs-foEs is smaller) and when the morning sequence has an especially high blanketing frequency, the afternoon sequence will also be high blanketing.
- Ess is seen over a wide area (Brisbane to Canberra), as the long lifetime suggests.

These are good observations, as data on sequential sporadic E layers at Australian stations verifies.

It is unclear why these results have not been effective in changing people's ideas about sporadic E. Evidently, from the early work, sporadic E at high altitudes was linked to the peaks in occurrence of sporadic E at lower altitudes.

Observations have been reported many times in the literature (e.g., see Thomas, 1956 for pre-1950 references). Thomas (1956) appears to have been the first person to suggest atmospheric tides could be responsible for sequential sporadic E. Evidently sequential Es is less prevalent at European stations than at Australian stations (Whitehead, 1970). Notwithstanding, MacDougall (1974, 1978) used sporadic E data from the global ionosonde network to explore the possible associations with atmospheric tides. More recently, Wilkinson et al. (1992) demonstrated that the formation of a long lived sequential sporadic E layer was consistent with wind fields predicted by the NCAR Thermospheric and Ionospheric Global Circulation Model, or TIGCM. The modelling successfully showed that windshears in the neutral atmosphere, due to atmospheric tides, together with the local electric field offer a satisfactory explanation for the appearance of a long lived descending sporadic E layer. This result showed the potential for the TIGCM to model sequential sporadic E and offers the prospect that a plausible cause-effect relationship can be deduced for some sporadic E formation. How important these processes are remains to be seen.

In this note, the sporadic E sequence modelled by Wilkinson et al is presented, together with hourly ionosonde data, demonstrating both the appearance of sequential Es on ionograms and also in scaled data. Following this is a discussion of the results, the problems and comments on

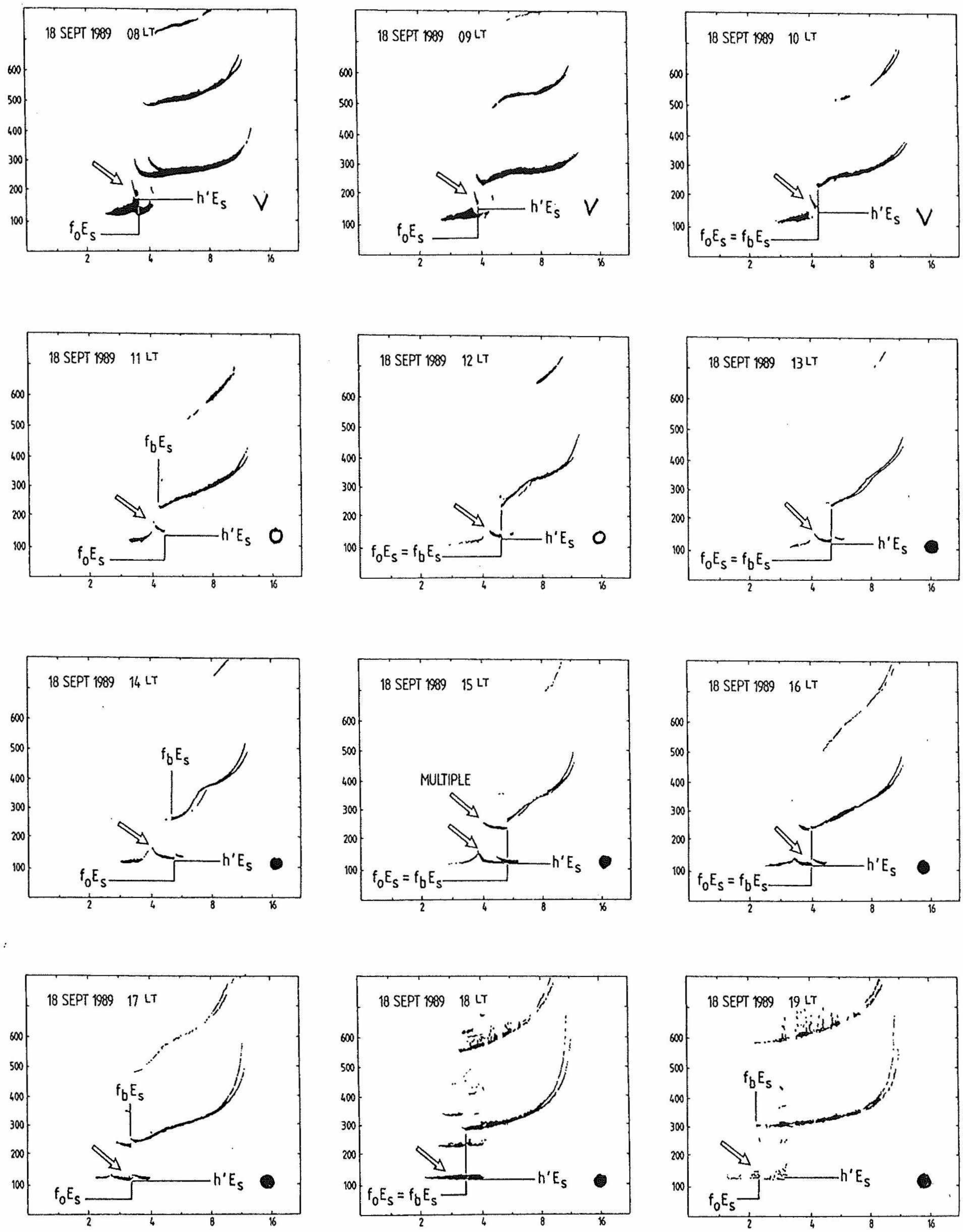


Fig. 1. A sequence of hourly ionograms recorded with the IPS-4B ionosonde at Townsville. The unfilled arrow indicates where the sequential sporadic E layer is, the horizontal line indicates where h'Es was scaled and vertical lines are used to indicate foEs and fbEs. The symbols used to code the level of confidence in the h'Es ploted in Figure 2 are shown to the right of the h'Es label.

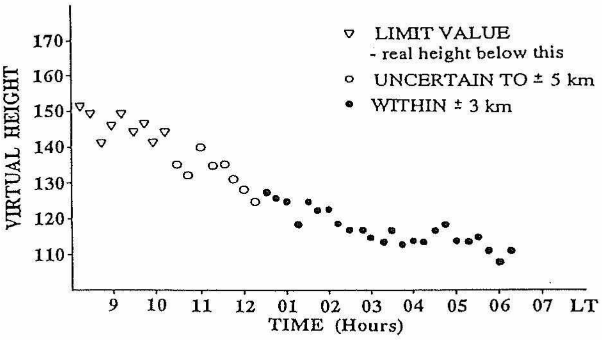


Fig. 2. The corrected h'Es virtual heights for the ionogram sequence in Figure 1 are displayed for the 15 minute ionograms.

possible future work.

2. View of the layer descent

During the September 1989 SUNDIAL campaign, descending sporadic E layers at Townsville were observed on several days and the best example was selected for study.

The sequence of hourly ionograms shows the development of a sequential sporadic E layer at Townsville, 18 September 1989 (Figure 1). The local time of recording is displayed in the upper left hand frame of each ionogram. The vertical axis is virtual height with vertical markers every 100km in virtual height. The horizontal axis is logarithmic in frequency, measured in megahertz. The sporadic E layer is identified with an arrow, foEs and fbEs are identified by a vertical line and h'Es by an horizontal line.

Initially, a layer is seen with an electron density only slightly greater than the normal E layer but with a large virtual height that is difficult to measure accurately due to retardation. McNicol and Gipps (1951) state the Ess sequence starts with a thicker layer breaking away from the F region. This is not always the case, as shown in Figure 1. Possibly this is a matter of the extent of ionisation affected or maybe it is a matter of qualitative interpretation. Because of the low sporadic ionisation, the underlying normal E region retardation effects are significant. These increase the virtual height making it a biased estimator of the real height. While allowance for retardation effects is possible, it is likely that the real heights are biased too high if the electron density of the sporadic layer is not 30% to 40% greater than the electron density in the underlying normal E layer.

As the layer descends, the electron density increases and is probably accompanied by layer thinning (McNichol and Gipps, 1951 and Thomas, 1956), and the virtual height becomes a better estimator of the real layer height. Often, during the layer descent before noon, as in the example, the normal E layer and the sporadic layer increase in peak electron density at a similar rate, with the sporadic layer being just greater than the normal E layer. As foE increases, the layer remains visible, but is only slightly higher in electron density than the normal E region. By local noon, the layer is below 130 km. The normal E layer electron density, which is solar controlled, then begins decreasing but the sporadic layer electron density either stays constant or increases while the layer continues to descend. Clearly, in the example, much of the time the sporadic layer virtual height overestimates the real height. However, by 1400 LT the sporadic layer critical frequency is large enough for the errors in reading heights off analogue film to be larger than the retardation effects from the underlying normal E region. The sporadic E layer remains detached from the normal E region until 1500 LT when it appears attached on the ionogram. Prior to 1500 LT it is called a high-type sporadic E layer and afterwards it is cusp-type sporadic E. Near sunset the layer breaks up, although in this sequence sporadic E continued to be present well into the night. It is unclear whether this ionisation is maintained by the same processes thought responsible for the daytime descending layer.

In Figure 2, the corrected values for the sporadic E virtual heights, both good values from below 130 km and with probable bias above this level, link together well. The layer is descending and for the later stages there is a rate of descent of roughly 5 km per hour which falls in the range of previously estimated descent rates (Whitehead, 1970). The rate of descent decreases as the layer approaches 100 km, as has been observed by other workers. After reaching this level, the layer dissipates. The region of interest is the mid height range between where the bias is small and where the layer approaches a "saturation region". It seems likely that the layer descent is controlled by a major wind shear influence, resulting in the long lived nature of the layer as it descends.

People unfamiliar with ionograms thought, on seeing these examples, that the layer may not be above the station. There are, however, a number of features that confirm the layer is overhead. A notable feature of this sequence is that, for much of the time, the blanketing frequency for the layer is almost equal to the layer critical frequency. This strong evidence that the layer is overhead has been cited by other authors. It assumes that the F region is overhead; a good assumption at these latitudes during the daytime. By 1500 LT, a multiple for the layer corroborates this fact. Finally, in the example shown, the layer is present for roughly 12 hours, making it likely that it was overhead.

3. Presentation of hourly data

Slowly descending sporadic E layers can be identified using sporadic E virtual height data scaled regularly from ionograms, together with other scaled data from the sporadic E layer and the normal E region.

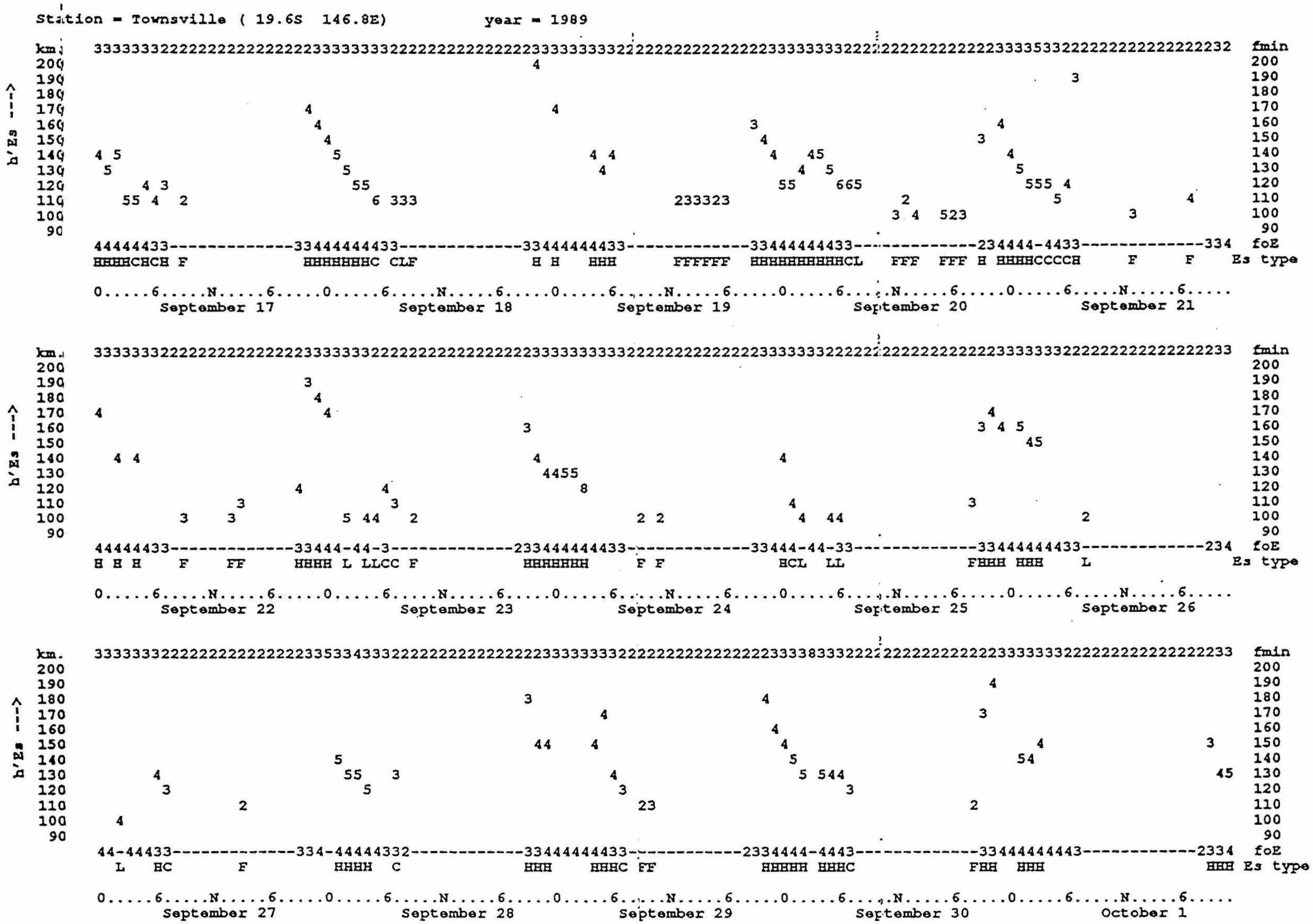


Fig. 3. Hourly data for the period 17 September to 1 October, 1989.

Occurrence of Sporadic E at Townsville (19° S).

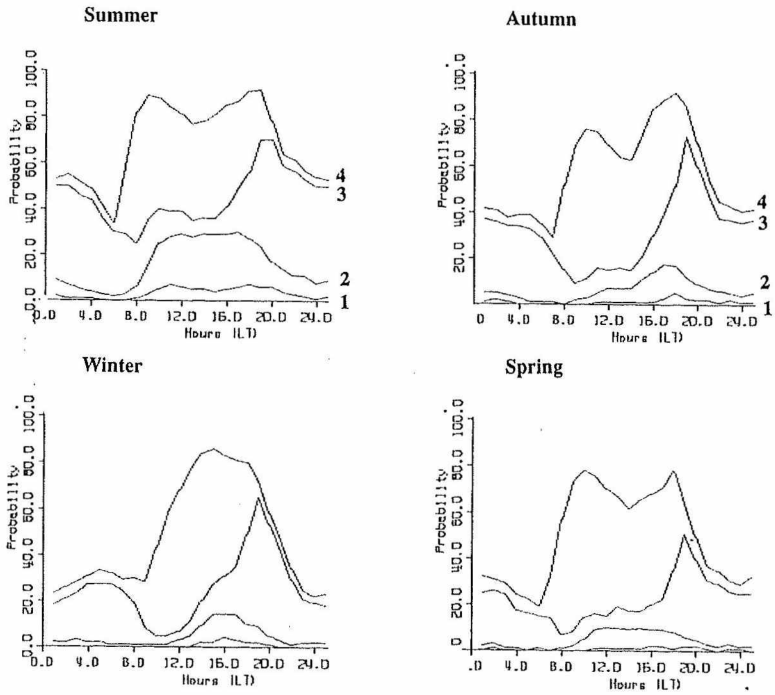


Fig. 4. **Four probability levels for sporadic E occurrence are shown:**

1. **Probability foEs > 7.5 MHz.**
2. **Probability foEs > 5 MHz.**
3. **Probability foEs > foE + 1 MHz.**
4. **Probability that Sporadic E is present.**

These features are shown in Figure 3. In the figure, the highest observed ordinary wave reflection from the sporadic E layer (foEs), rounded to the nearest megahertz, is displayed on the diagram at the virtual height of the sporadic layer. This value is bracketed by fmin (top line) and foE (bottom line), defining a lower frequency threshold below which sporadic E ionisation cannot seen. The type of sporadic E is plotted beneath the time series. There is no allowance for possible bias in the virtual heights recorded, but the frequent intrusions of sporadic E starting from apparently great altitudes and then descending, near local noon, are clear on several days. Because of the small differences between the sporadic layer maximum and the normal E layer electron density, it is not surprising that several sequences are broken, or start at low altitudes. The predominant feature of the figure are the clear descending sequential sporadic E layers, characterised by falling virtual heights as the day progresses. Inspection of the ionograms recorded for this period shows this even more convincingly.

4.Discussion of the results

Summarising these observations, descending sporadic E layers have been observed at many sites around the world and attempts have appeared in the literature to associate them with a source of wind shear, such as atmospheric tides. The reasons for making such an association are clear here; the layer descent is slow, occurring over an appreciable length of time and is roughly repetitive at the same time each day.

In this section, some possible areas for future work are indicated.

4.1.Some sporadic E statistics

As an example, some sporadic E statistics for Townsville are presented in figures 4 and 5.

In Figure 4, all sporadic E observations recorded at Townsville between 1983 and 1990 are displayed using four different probability thresholds of sporadic E activity that have appeared in the literature. Curve 1 is for intense sporadic E, defined as the probability that foEs will exceed 7.5 MHz. Curve 2 is a more familiar threshold; the probability that foEs exceeds 5MHz. This threshold has been used to construct world wide maps of sporadic E occurrence and is introduced in Smith (1957). Curve 3 uses a threshold similar to one introduced by Piggott and also, earlier, by J W Wright. I have included it here to illustrate another option for dealing with sporadic E. This threshold takes the position that if foEs is sufficiently larger than foE, then it is important. This is a way of eliminating solar dependence of sporadic E occurrence so that the general behaviour can be studied. At night the threshold was set at 2MHz and during the day, when foE is measured, a threshold of (foE + 1 MHz) was chosen.

All three of these statistical thresholds eliminate the type of sequential layer shown in figures 1 and 2 for much of their development. Therefore, a fourth probability option was introduced. Curve 4 is the probability that sporadic E is present and is calculated as the probability that h'Es is nonzero. This is valid because h'Es is always recorded at Australian stations if any sporadic E, other than slant type

Height Behaviour of Sporadic E at Townsville (19° S).

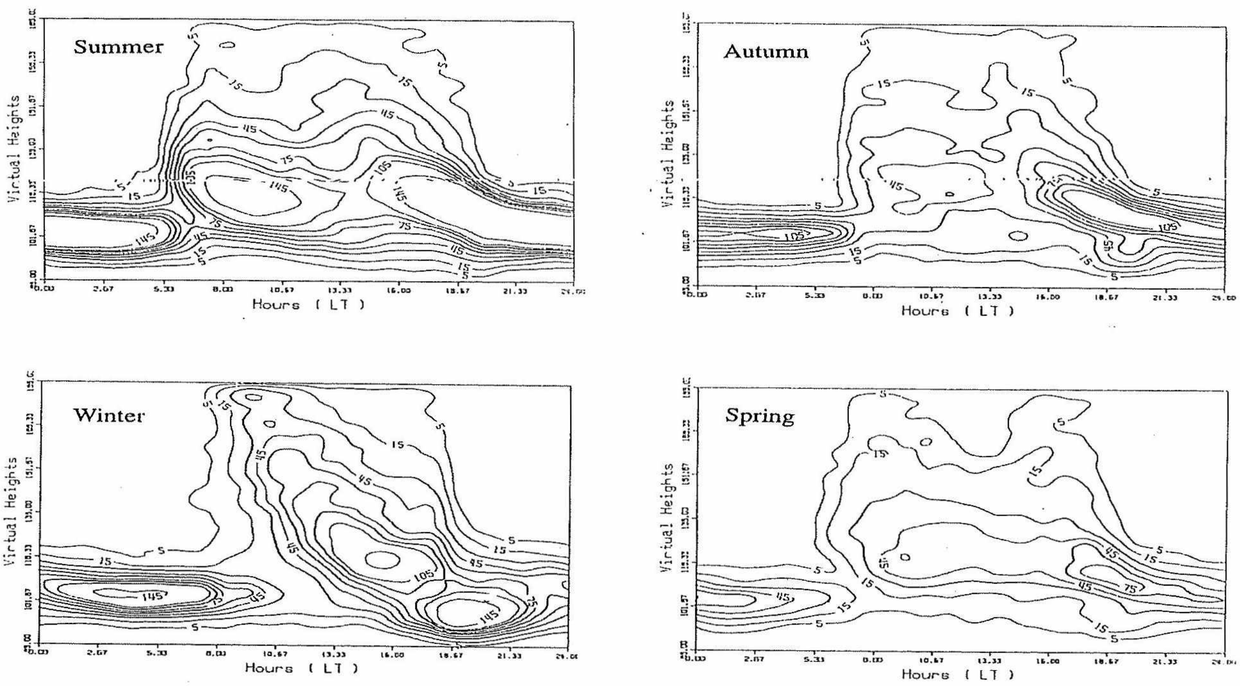


Fig. 5. The number of occasions sporadic E formed in a time (1 hour) height (1 km) cell was counted and selected counts (5, 15, 30, 45, 60, 75, 90, 105, 145) were contoured to give a visual impression of the behaviour of sporadic E.

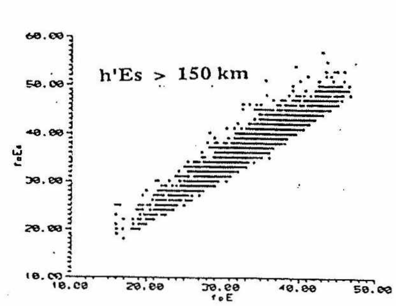
sporadic E, is present.

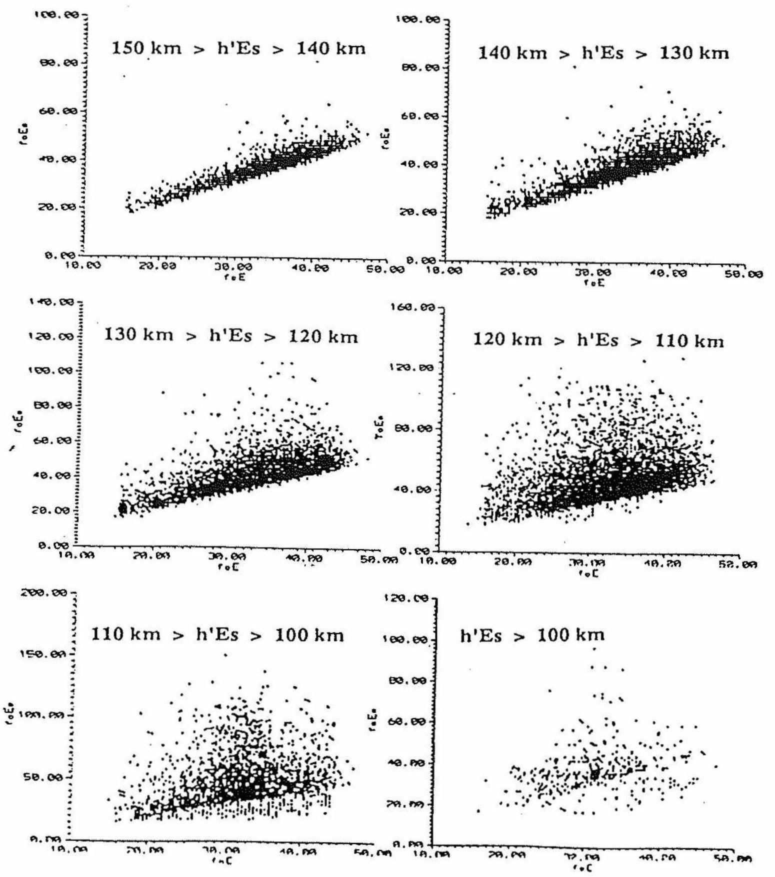
All these measures of probability have problems associated with them and need to be interpreted with care. However, they are useful here for illustrating sporadic E behaviour. Curve 4 shows clear double peaked behaviour for all seasons but winter. The curve also illustrates something most Townsville scalers know well — sporadic E is almost always present sometime during the day. While foEs may not be large, the layer is nevertheless present in all seasons. Curve 2 shows the more familiar seasonal behaviour reported in the literature for sporadic E. Daytime, summer occurrences are significantly higher than for other seasons. There is no double peaked probability distribution, as mentioned by McNichol and Gipps, but instead there is a broad maximum. However, curve 1 does show two peaks in sporadic E occurrence. There is a clear tendency, in curves 1 and 2, for sporadic E to be more likely in the afternoon, prior to sunset, for all seasons other than summer.

Figure 5 is a more unfamiliar presentation of sporadic E. From 1983, Australian scalers were asked to scale all heights of ionospheric layers to 1 km. While the heights recorded this way were not thought to be this accurate, scalers had already shown they were able to scale common ionograms to this level of repeatability. These data have been sorted into bins 1km by 1 hour producing an array of counts that was contoured for counts of 5, 15, and then in steps of 15 up to 105, with a final contour for a count of 145. The selection of contours was a little arbitrary as the display of data was intended to visually present the height variability of sporadic E at Townsville rather than explore it statistically. A count of 5, for summer, means that sporadic E was seen in a bin on 5 occasions out of roughly 900 possible occasions. While these are small probabilities, there is consistency in the counts that is particularly clear for winter in Townsville - my best example, I admit. This figure shows the tendency for sporadic E to organise into height - time regimes. Patterns seen at high altitudes tend to be linked to lower altitudes; not surprising, considering Figure 2. These type of data have been explored by MacDougall (1974, 1978).

Comparing figures 4 and 5, it is evident that the peaks in sporadic E occurrence in Figure 4 match the structure sporadic E shows in Figure 5. Summer, for instance, has two periods, in Figure 5, when descending sporadic E is likely to occur and two peaks in sporadic E occurrence are seen in curve 1 of Figure 4. In winter, Figure 5 shows only one period when descending sporadic layers are likely, consistent with the late afternoon peak in sporadic E occurrence for curves 1 and 2 in Figure 4.

Fig. 6. All hourly foEs data is plotted against foE for the period 1983 to 1990 for Townsville. The data is partitioned into seven groupings of the data according to the uncorrected h'Es recorded. The scales used are in 0.1 MHz units, the vertical scale having been adjusted to make best use of the available space.





These two figures offer a visual impression of the processes that appear important in the production of Townsville sporadic E.

4.2. E_2 relationship

The E_2 layer has been associated with descending sporadic E. The issue here is that E_2 has an identity in some locations as a normal solar produced layer, while when associated with descending sporadic E, as suggested here, it is a dynamic layer. At Uppsala, Derblom (1981) showed that E_2 descended through the E/F1 region to merge with the normal E. Earlier we had noted that E_2 could become Es. Here, E_2 has its own identity - a feature of the higher latitude maybe. The layer appears to descend at a rate of around 7 m/s in the height range 200-150 km, compared with 5.5 m/s for sporadic E in the region 150-120km. Derblom rules out any clear association between E_2 and Es, but does not preclude a possible association.

4.3. Valley effects

An important possibility, not yet explored, is the effect of a valley between the E and F1 regions. Clearly, foEs is not much larger than foE above 130 km so that, if the valley is moderately deep and wide, no descending layer will be seen. This offers a problem for detecting layers, but also a possibility for making indirect observations of the E/F1 valley. Observations of sporadic E during a solar eclipse have shown that the sporadic E layer can exist within the valley and be unseen for much of its descent.

4.4. Solar activity effects

Much of the literature on sporadic E emphasises that the layer must contain large numbers of metallic ions. The reason for molecular ions being thought less important is that a molecular layer could never reach the observed peak electron densities due to the more rapid chemistry in the layers. But do molecular ions play a part?

Figure 6, showing foEs plotted against foE, is a convenient display relating foEs to solar zenith angle. At greater virtual heights, above roughly 130km, foEs follows foE closely — the layer, when present, is solar controlled. This is obvious because high (Ess) sporadic E layer electron densities are never much different from the normal E region electron density. For virtual heights above 140km, foEs is never more than 1.0 MHz greater than foE at Australian stations — I searched over 20 years of data for five stations, and over a solar cycle for another five. It is a fundamental property.

Sporadic E layers are a mixture of ions. At greater altitudes, molecular ions may be more important - I deduce this from the solar control aspect. As the layer descends, metallic ions become the predominant feature of the layer. This seems to me to be moderately complex and, other than Derblom's report, I don't think it has been considered, since people appear to have concentrated mainly on sporadic E layers below 120 km.

5. Conclusion

These results have demonstrated that h'Es has value as a sporadic E parameter and may bring new insight to the sporadic E statistics.

The results show there is a number of interesting and potentially fruitful areas for further research to increase our understanding of this complex, but common, phenomenon in our atmosphere. There still seems to be much that can be learned from sporadic E using conventional hourly ionogram data.

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Inventor of the Beverage Antenna dead at 99

Dr Harold Beverage, the inventor of the "Beverage Wave Antenna" died in Port Jefferson, Long Island, NY at John T Mather Hospital at age 99. He had a long and illustrious career in communications and radio research. In 1938 he received the Edwin Armstrong Medal for his pioneering work on aerial systems and the citation included the statement that "the Beverage Wave Antenna was the precursor of the wave antenna of all types". Then in 1957 he was awarded the Lamme Gold medal from the American Institute of Electrical Engineers (now absorbed into the IEEE) "for his achievements in the conception and applications of principles basic to the progress in national and world-wide radio communications". He received many other awards but it is worth mentioning that he was 30, when in 1923, he received the Morris Liebman Memorial Prize for developments in transoceanic radio.

Most of his career was at RCA, where, in 1920 at 27, he was put in charge of developing receivers for global communications. Then, in 1929 he was promoted to chief research engineer in communications and in 1940, he stepped up to vice president for research at RCA Communications, Inc. In 1958, he retired from RCA to become a consultant.

I often had pleasant conversations with Dr Beverage during US National URSI meetings in the 60s and 70s where he was a keen participant. In particular I welcomed his advice on the theoretical development of horizontal grounded antennas for ELF and VLF transmission. Yes, they do radiate vertically polarised signals!

A delightful little book† entitled *Genius at Riverhead* (a profile of Harold H Beverage) is now available from Alberta L Wallen, North Haven Historical Society, North Haven, Maine. As she attests, "He was destined to make significant impact with one of the greatest industries the world has ever known — Radio Engineering" and I could add — Radio Science, particularly Commissions A, B, F and G of URSI.

James R Wait (Associate Editor, Reviews)
Tucson, Arizona
USA

† Library of Congress Catalogue Card No. 87-62783 (1988).

Looped Demonstrations on Global Dynamics of the Ionosphere and Optimum Regimes for Ionospheric Communications - *A software demonstration prepared by the Russian Academy of Sciences.*

A package of seven computer film loops has been prepared to demonstrate different aspects involved in supplying reliable communication links. There are three groups of demonstrations: propagation predictions (2 examples), antennas (2 examples) and ionospheric modelling (3 examples). All the demonstrations are in the form of films, a powerful method for illustrating the examples modelled. The software is the product of a long term effort at IZMIRAN.

The software is supplied on two 3.5 inch disks to run on a PC under DOS with a VGA screen and, preferably, a 386 processor with 4MB of free RAM. Installation is straightforward and creates a series of directories in the root directory under the directory name demo. These take up roughly 5 MB of space. The demonstrations can be run as a group, using the two supplied batch programs, or separately. There are two language versions: English and Russian. Each of the three groups of demonstrations is discussed next.

The antenna demonstration is a well planned display showing the changes in the polar diagram for two antennas as they are used for a stepped range of frequencies. This is a good educational display showing clearly how frequency affects antenna usage.

The ionospheric modelling displays use the International Reference Ionosphere (IRI) and topside data from the Intercosmos-19 ionospheric sounder to illustrate how the global ionosphere changes over a day. Each is worth commenting on. Each frame of the Intercosmos-19 display shows the ionospheric cross-section in the satellite orbit plane. A full days orbits make up the complete demonstration. This is an excellent display of the diurnal and longtitudinal changes in the ionosphere. Although the presentation is possibly unsuitable for scientific study, it is valuable for visualisation purposes.

The second demonstration in this group matches the topside observations to the IRI bottomside to produce a complete picture in the global ionosphere. The third demonstration repeats this using only the IRI outputs, showing a strong contrast in detail between model and data.

The final group of two demonstrations illustrates examples of the IRI used to make propagation predictions. There are a wide variety of possible ways this information can be displayed and for some these displays will be less impressive than the others collected together here. Clearly, the wide variety of possible options for presenting propagation predictions makes it difficult to satisfy everyone. However, the general principal of using a time dimension, in the form of a repeating film loop, to illustrate the effects of the ionosphere on propagation is a good educational device and some of this potential is illustrated here.

The main purpose of the package is to offer examples of the type of applications that have been developed, and can be developed, at IZMIRAN. The packages developed to date can be generalised to other applications. In this review the demonstrations have been considered at three levels: as demonstrations of a wider range of possible software, as examples of visualisation and as a set of educational displays in their own right. This group of demonstrations is worth considering in any of these roles.

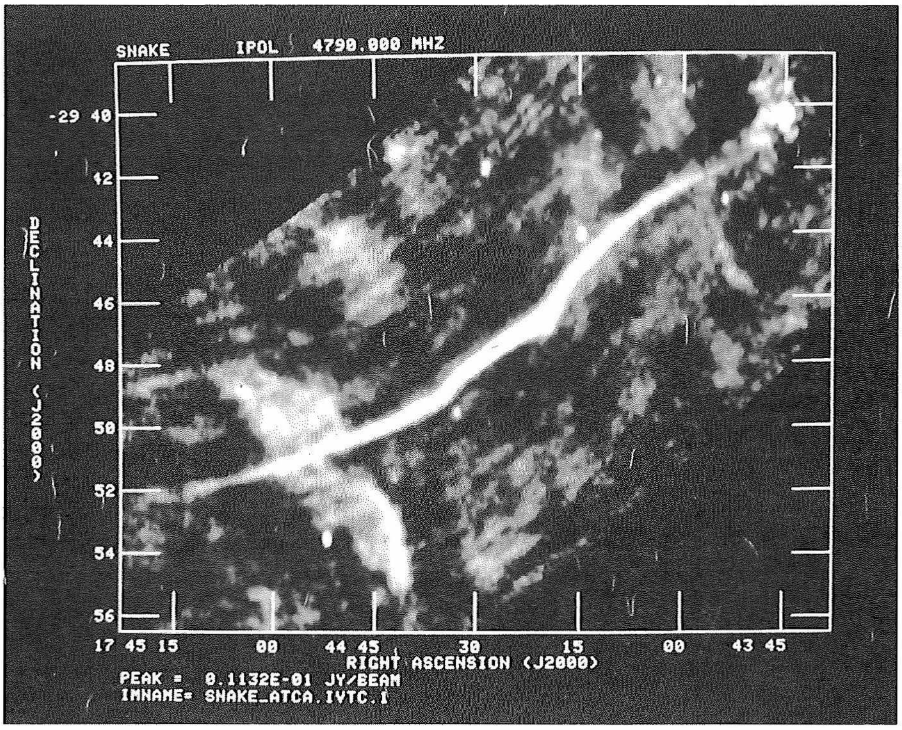
To date there has been a limited distribution of the software, but copies can be obtained from:

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.**

We regret being unable to reproduce the advertisement for *RADIO SCIENCE* in adequate quality until the next issue. In the meantime we assure all subscribers to *the Radioscientist,* and those who receive it and/or the *Bulletin* as officers of URSI, that they are entitled to the same discount as are AGU members. We also repeat that all subscriptions to *the Radioscientist* which would have run out in June or September have been extended to the end of 1993 at no extra charge.

THE SNAKE



Imaged from 6–cm waves, the Snake is the slightly bent object running diagonally from top-right to bottom-left. The Galactic Plane runs across the top-right corner of the frame oriented perpendicular to the general line of the Snake. The bright source just in from the top-right corner is a small part of a large ring-shaped supernova remnant which is centred close to the bottom-left corner of the frame. The other compact sources dotted around are probably extragalactic background sources.

THE SNAKE (G359.14-00.20): Discovered on a MOST (Molonglo Observatory Synthesis Telescope) radio (6 cm) image and studied with the VLA (Very Large Array) and more intensively with the ATCA (Australia Telescope Compact Array), the latter providing high quality data for high resolution, wide-field imaging of both the total intensity and the polarisation characteristics, the Snake is a narrow, thread- or filament-like object located about 50 arc minutes from the Galactic nuclear source, Sgr A. There are several other filaments which lie in the direction of the Galactic Centre, the only place in the sky in which they are found, and there is also independent evidence which suggests that the Snake does lie in the Galactic Centre rather than being seen in projection. However, while it bears strong similarities to these other filaments, the Snake does have some features which set it apart:

- it is the longest known isolated filamentary source in the region at over 20 arc minutes in length (50 parsecs), comparable to the multiple filaments of the Sgr A "Arc" feature;
- it is further from Sgr A than any other known filament;
- it extends almost perpendicularly into southern Galactic latitudes — the others all lie north of the Galactic plane and are at orientations consistent with a poloidal configuration of the Galactic magnetic field (assuming that these linear features are tracers of the magnetic field);
- these last two points place it outside the so-called "Galactic Centre Lobe", in conflict with at least one proposed model of the Galactic Centre activity in which the filaments lie on the Lobe's surface;
- the Snake is not smoothly curved and displays kinks and bends;
- at high resolution the Snake is seen to consist of several, narrow sub-filaments which apparently intertwine, behaviour not seen in the other threads, although the Sgr A "Arc" does consist of multiple, almost parallel filaments.

The most recent ATCA observations have shown the Snake to be highly polarised (up to 35% of the total emission), but not along its entire length — the region north of the prominent central kink is not seen in polarisation. The reason for this is currently being investigated. Estimates of the rotation measure for this source give values in excess of 5000 radians per square metre near the central kink, one of the highest values ever measured. However, this is not in itself sufficient to explain the lack of polarisation seen. Theoretical interpretation of these observational results is currently being undertaken in collaboration with scientists of the Research Centre for Theoretical Astrophysics at the University of Sydney.

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