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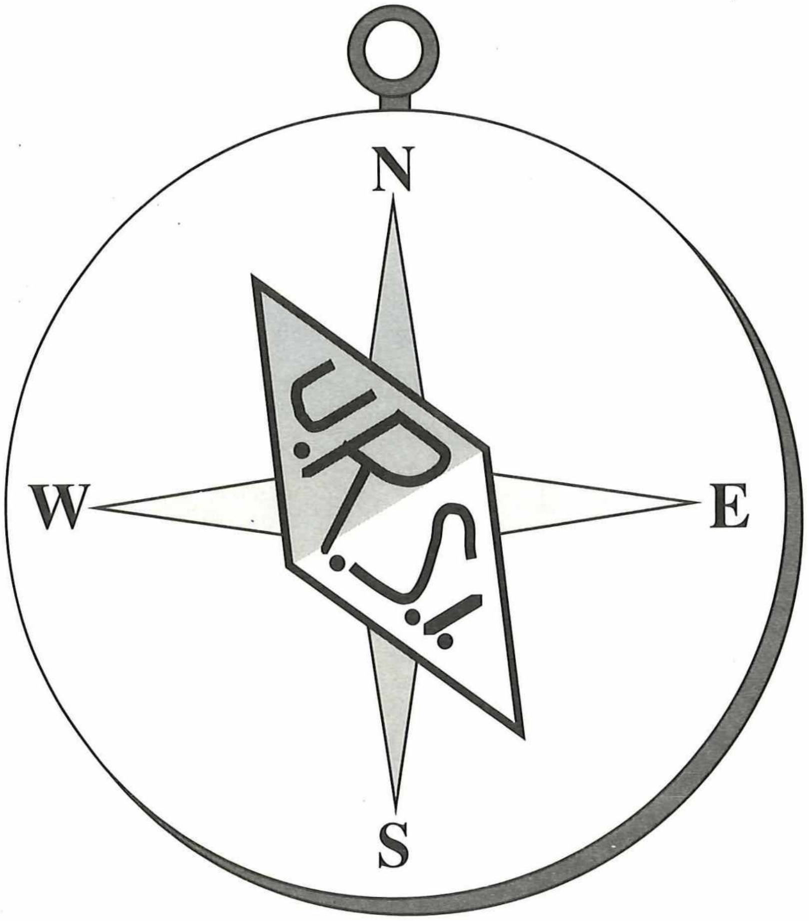

Changing Times

The RADIOSCIENTIST

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NOTICE TO CONTRIBUTORS

All material should be mailed direct to the Editor, preferably on Word 4 (Mac) on diskette. "Flat" or pure ASCII text files on diskette or email are acceptable, as is paper. Deadline is six weeks before issue date but contributions are welcome at any time. The Editor reserves the right to to accept, reject, defer and/or edit any material and all material submitted.

COVER: URSI in a changing environment (symbolised by a changing geomagmetic field — see editorial)

Radioscientist-Bulletin

I had intended to make *the Radioscientist* bimonthly from the last issue and in phase with the IEEE *AP-S Magazine* with which we have a close association. However, it is essential that *the Radioscientist* be in phase with the *Bulletin* because from now on they will be issued together and the *Bulletin* is limited to 4 issues per year. To keep faith with our subscribers (over 100 and still growing) we will —

- Extend their subscription to provide the same number of issues. For most, this means extending the subscription until June, 1993, the last issue before the Kyoto G.A.
- Include the *Bulletin* at no extra charge, both sent by air, for the duration of the subscription (this is less than the cost of the *Bulletin* alone).
- Endeavour to provide *Radioscientist* subscribers with the benefits of de facto individual international membership of URSI (URSI circulars, discounted journals, etc.)

On the other hand, *the Radioscientist* will be sent only to the official members of Member Committees, Board Officers, etc., and to the subscribers. So if you are not in one of these categories, this is the last issue you get if you don't take out a subscription! If you are in both categories we will either provide a refund of your subscription or hold it until you are no longer in the "official member" category.

The relationship of *the Radioscientist* to URSI will become more apparent with this mailing together *so why not*, you may ask, *fuse the two magazines into one?* **Good question.** After all, URSI bears the cost of printing and distributing both (less the subscriptions and advertising revenue).

But there is a very good answer. The *Bulletin* is the official voice of URSI, it is directly published by URSI and it is under the direct responsibility of the Secretary General. *The Radioscientist* is published by Radio Science Press, a non-profit company set up by URSI in Brussels (see top right, previous page). The editorial content is the responsibility of me, the Editor. The Editor, being appointed by URSI, is answerable to URSI. However, all opinions expressed in *the Radioscientist*, unless identified by source or author, are mine and not necessarily (and maybe not even usually!) the official view of URSI. A statement to this effect appears on the previous page as it has in every issue of *the Radioscientist*. An important part of the function of *the Radioscientist*, not well utilised, is to act as a forum for radioscientists. In this issue and immediately below I express my personal view. Following this is a Guest Editorial in which Ed. Jull expresses his personal view. Some readers may see some conflict in these views, some might even be lead into writing *Letters* to *the Radioscientist*. If that is the result then *the Radioscientist* will have become the forum we need.

Changing Times

The political change over the last few years or even months is enough to send a cartographer crazy (as a cartoonist has portrayed). The socialist state and even the welfare state like NZ have been largely taken over by the market economy philosophy. URSI survived well in the confrontational politics of the past by being apolitical, perhaps one of the first and most apolitical of the International Scientific Unions (ISU's). Market economism, if there is such a word, is taking over the world faster than communism ever appeared to be and with little opposition. I'll leave you guessing as to where my sympathies lie, since URSI and everything to do with it should remain apolitical.

But is being apolitical adequate response by URSI? Part of the market economy philosophy is that everything is "accountable". This means that everything must benefit some person or group or even the whole country, and that is who has to pay. In my university Science Library, every journal subscription was on the list for cancellation unless adequately justified. Justification meant showing that cancellation would be more costly (in some convincing sense) than continuation. I expect this is familiar to most of you, so what about this? Your National Academy (or whatever is the body which pays ISU subscriptions) notifies all National Committees (as they are usually called internally whatever URSI may do) that the level of subscription to their ISU, or even the continuation of adherence to that ISU, has to be adequately justified. URSI Member Committees of the larger and wealthier "territories" (usually referring to the countries) may never experience this if only because the financial pressures are less for them (the URSI subscription paid in terms of the GNP is less at this end of the spectrum of URSI members). However, if you are on an URSI Member Committee at any end of the spectrum it would be sensible to think how you would make an adequate justification in market economy terms (maybe the only ones which will work).

You may consider this need to justify to be unlikely in your case but I have been in the position myself and know of two or three others in this situation. You may also feel I'm sowing ideas (of resignation from URSI) which would be better left unsaid. But the scientists and engineers of URSI would hardly want their country or academy to resign and surely their politicians who see URSI only in market terms don't read the Radioscientist! To ignore the problem and not even have some answers ready could be much more dangerous.

In making such a justification to one's URSI subscription payer it may not help to point to a large number of scientists and engineers who get individual benefits from URSI (like magazines or journals), as in the market economy philosophy you have then identified the people who should pay instead (e.g, a national society of radioscientists). Rather, you may have to point to economic benefits to the payer of the subscription and of the travel costs of the Council representative at URSI GA's — benefits of belonging to URSI which are not available free to non members, and not independent of membership level except for voting.

[continued on page 105]

Scanning the issue

We start this issue with a new feature we hope to have in all future issues — the **Guest Editorial.** This first one is by Edward Jull, our President. It not called the President's Page or some such, for two reasons. Firstly because he doesn't want to commit himself to writing one for every issue and did not sign this one as President. Secondly because the President's Page would appear to be giving the official word of URSI. If it was, it should be in the *Bulletin*. The whole point of keeping *the Radioscientist* separate is that the Editor and the Guest Editorial authors can feel free to write their personal views. As such, I hope that Ed. Jull fills this role frequently.

We have had articles about on-going projects like that on SOUSY in the last issue and historical articles on projects and institutions like one later this issue. But the next article in this issue is about a proposed project or instrument, **H^{i}Scat**. The authors are a team of five Swedish and Russian scientists who see this as a third generation radio probe for the ionosphere, magnetosphere and the solar system, and combining and exceeding the modification abilities of the ionospheric heaters for active experiments. May it come to reality!

The feature article is a tribute to a very well known URSI personality, particularly within Commission G, **Jack Gledhill**, who died of cancer in June, 1988 (see the Bulletin, September, 1988). In its original form (**"Twenty Five Years......."**), this article was written by Jack Gledhill shortly before he died and was published only internally in South Africa. His successor as Director of the Herman Ohlthaver Institute for Aeronomy, Allon Poole, kindly agreed to update this to **"Thirty Years..."**

As you may have noticed on the inside cover of the October issue, James R. Waite is now the **Review Editor**. The meaning of this title is expandable but it primarily concerns book reviews at present. His first reviews appear in this issue. Although he has reviewed both of these himself, he will be calling on his colleagues as well to review in later issues.

Finally, another of **Alan McCord's reviews** of analysis and graphics software: two low cost packages for the PC by MicroMath.

URSI and the IEEE: What is the difference?

After the question "What is URSI?", the second question is usually "What is the difference between the IEEE and URSI?". It should not be necessary to deal with the first question here, but the second brings out some interesting comparisons. Both organizations depend on volunteers. Since jobs are sometimes more abundant with volunteer organizations, I have worked for both, and ought to be able to answer the second question.

The IEEE is undoubtedly a most successful organization. It publishes first class journals and organizes important conferences in electrical, electronic, computer engineering and computer sciences on a scale surpassing all similar organizations. Three quarters of its more than 320,000 members are in the USA, but its membership growth on a worldwide basis now considerably exceeds that in the US! It calls itself a "transnational" organization and this becomes more of a reality with every conference and meeting it holds outside the US, and with every non-American elected to an IEEE position.

URSI is certainly international already, but its membership size is smaller than that of the IEEE by a factor of about 10^4. This is because territories, not individuals, are members. An advantage of this policy is that there are no individual membership fees to be paid. Only countries pay. The disadvantage is that with no individual membership lists there is a lack of direct mail contact with most of our colleagues. The URSI Secretariat plans to gradually overcome this problem, but the solution will probably require some sort of subscription fee. *The Radioscientist* is of course an important part of URSI's effort to increase its visibility and improve its service to individuals. But these have never been a priority for URSI as they must be for the IEEE, since paying and voting members demand service.

In addition to having different priorities, subject areas of IEEE and URSI do not coincide. At least two-thirds of IEEE society member activities lie outside the scientific commission areas of URSI. The IEEE Computer Society, with 107,000 members, is by far the largest example, but others are Power Engineering, Control Systems, Industry Applications, Management, Education, etc. Similarly some URSI Commissions are not represented in IEEE. H and J are the obvious examples. So subject areas of IEEE and URSI are not subsets of each other, but the organizations have much in common and some similar objectives.

URSI's prime objective is to promote international cooperation in radio science. This is surely an objective of IEEE also, but not its main purpose. By its nature IEEE must first serve the professional needs of its members by providing for the exchange of new scientific and technical information through publications and conferences. Some US IEEE members feel their economic interests should also be served. Fortunately URSI does not have to deal with that problem.

URSI's different primary objective implies positions different from the IEEE on several issues. URSI's effort to promote radio science in developing countries is an example. We do this by trying to identify and encourage colleagues in these countries, by sponsoring publications which may be particularly helpful to them, and by contributing to the activities of the Third World Academy of Sciences in Trieste. The amount URSI spends on these activities is modest. Given the resources it could do much more. Closely related is the URSI Young Scientist Programme, also of great potential long term benefit, but which can no longer be described as modest in scale. Some IEEE Societies are beginning to show an interest in this kind of outreach, but generally there does not seem to be much popular support for activities tangential to what most members want from the IEEE. Clearly, developing countries and young scientists' activities coincide with URSI's prime objective. That URSI can do it — and is indeed encouraged to do it by its financial sponsors, the academies of the member committees and ICSU — is because the programme does not depend on individual members for support.

IEEE's international expansion may concern some national electrical engineering societies, but should be welcomed by URSI. In Canada, where the IEEE has long dominated the electrical engineering profession, the effect has been the growth of IEEE regional national consciousness. It may be region 7 to our US colleagues but it is quite definitely "IEEE Canada" to Canadian electrical engineers. URSI is alive and healthy in both the US and Canada not *in spite* of IEEE, but in no small measure because of it.

Close cooperation between URSI and the IEEE Antennas and Propagation Society has always existed. Partly this is because USNC/URSI and IEEE/AP-S officials are often interchangeable. For example the last AP-S president will become the next USNC/URSI chairman. The main form of this USNC/URSI - IEEE/AP-S cooperation is a joint international symposium held annually for the past 20 years. It has been held in Canada, together with Canadian URSI, three times since 1980. The IEEE Geoscience and Remote Sensing Society has gone even further internationally with URSI. The annual IGARSS meetings have alternated between the US and Europe or Canada, and are jointly organized and financed together with either USNC/URSI or URSI itself. These meetings also provide some support for graduate students and colleagues from developing countries. Since international expansion of these IEEE societies generally helps promote international cooperation in radio science, it is rightly encouraged and assisted by URSI.

As a member of the International Council of Scientific Unions (ICSU), URSI adheres to the principle of free circulation of scientists. It therefore will not co-sponsor a meeting where attendance of scientists will be restricted in any way for political reasons. URSI cannot be subjected to the policy of any nation or any group of nations, and represents no threat to their national societies. As such it has an international acceptance which IEEE, by its nature, cannot always expect to have. In a world of rapid technological and dramatic political changes, to which both have contributed effectively, IEEE and URSI continue to cooperate and also to play important independent roles.

E. V. Jull

HiScat — The Third Generation Scatter RADAR

Background

The plasma processes in the auroral magnetosphere and ionosphere continue to be a prime target for space physics research. Despite major efforts to investigate the complex processes in these regions by means of space-borne and ground-based diagnostic instruments, there are still many important questions to be answered in order to gain a better understanding of this near-Earth space environment.

In 1984, a group of scientists at the Uppsala Division of the Swedish Institute of Space Physics put forward a preliminary proposal to the space physics community for a new and versatile scatter facility to be built in northern Scandinavia. Realising that the first generation instrument for probing the ionosphere, the ionosond, was developed in the 1930s and the second generation instrument, the incoherent scatter radar, was developed in the 1960s, the Uppsala group wanted to pursue the ground-based investigations of the near-Earth plasma into the 1990s and the new millenium with a third generation instrument.

Motivated by new experimental and theoretical discoveries, and shortcomings and limitations of existing facilities, it was proposed that the new facility should be operated in the frequency range 5–50 MHz with an equivalent average output power well above 1 GW and a versatile, very high-gain antenna system. The name for this new facility—an acronym for **H**igh latitude, **H**igh altitude, **H**igh power, **H**igh frequency, **H**igh performance, **H**eating and **i**onospheric **Scat**ter facility—was chosen in order to emphasise the novel and in many ways unique ideas in the proposal. Since this first proposal, discussions, theoretical studies and experimental verification of some of the original ideas have taken place. The outcome of this work is presented in this status report which will form the basis for a full feasibility study to be published later.

Why HiScat?

The aim for high altitudes and high latitudes is motivated by the need for ground-based diagnostics of the auroral magnetosphere where present and planned radar facilities (EISCAT VHF and UHF systems, Spitzbergen radar, STARE) are inadequate. The choice of the operating frequencies in the HF range, as opposed to the VHF and UHF ranges commonly used, is essential for the radar probing of processes in the tenuous plasma in the auroral magnetosphere. When used as an ionospheric incoherent scatter radar, will probe small wave vectors not accessible with present day instrumentation in the auroral region. The use of HiScat as a "passive" probing radar will be one of the most important operating modes. It is important to keep in mind that in this mode both the cold, weakly magnetised ionospheric plasma ($\omega_{ce} \ll \omega_{pe}$) and the hot, strongly magnetised magnetospheric plasma ($\omega_{ce} \gg \omega_{pe}$) may be probed.

By utilising the high power of HiScat and drawing on experience from ionospheric HF modification experiments made during the past decade, it will be possible to use HiScat for nonlinear "active" probing of the ionosphere and magnetosphere. HiScat will be the first ground-based facility where capabilities for nonlinear diagnostics of the near-Earth plasma will be built in from the start. This will provide unique possibilities for completely new types of measurements.

The possible usages in solar, planetary and astrophysical investigations as well as in atmospheric investigations with conventional and improved MST techniques are other strong incentives for HiScat.

The location of HiScat in the Kiruna area, near the Esrange rocket range and satellite ground stations, not only facilitates studies of the plasma in a number of interesting regions of the magnetosphere (the auroral acceleration region, the polar cap, the plasma trough and the plasma sphere), but will also guarantee easy access to a wide range of supplementary diagnostics, including incoherent scatter radar observations and measurements in situ with instruments onboard rockets and satellites. The possibility to use HiScat for wind profiling, using MST techniques, will provide valuable meteorological support for rocket launches from Esrange.

Since the first proposal in 1984, the concept has been discussed further in the international space physics and astrophysics community. In particular, there is a large interest in and strong support for magnetospheric and ionospheric research with HiScat within the Soviet space physics community and scientific and technological studies have been undertaken both in the USSR and Sweden in order to study these aspects further. Also, discussions have been going on with Swiss scientists for the use of HiScat in solar radar investigations and with US scientists concerning radio astronomy applications.

In the present status report, completed and on-going studies related to the scientific and technological aspects of HiScat are presented. The comparatively large group of scientists presently involved in these studies are convinced that HiScat will provide unique possibilities for first-time studies of as yet unexplained phenomena as well as improved studies of previously known phenomena in the auroral magnetosphere and ionosphere and that it will redefine the forefront of ground-based space plasma physics.

Operational Modes

The original HiScat proposal was motivated by the need for an instrument to perform ground-based investigations of the magnetosphere, ionosphere and atmosphere of the auroral region not possible with existing facilities. It was found that this goal would be best fulfilled by the proposed versatile HiScat design with a high power facility operated at HF and low VHF frequencies. An important aspect of the versatility of the HiScat design is that the very same facility with its antenna system, transmitters, receivers and signal processing capabilities, can be operated in different modes:

linear sounding ("passive") radar mode, nonlinear probing ("active perturbation") mode, and receiving mode.

Sounding mode.

The most important usage of H^{i}Scat in the "passive" radar mode will be:

- Magnetospheric sounding by scattering off electrostatic turbulence in the auroral magnetosphere. Turbulence of this kind cannot be observed with existing radars but has been observed in satellite experiments and in recent HF scattering experiments using heating facilities as simple scatter radars. Magnetospheric scatter experiments using a facility specially designed for this purpose will render possible a detailed study of plasma turbulence caused by field-aligned currents, the formation of double layers, and acceleration mechanisms of electrons and ions.

Additionally, the following uses of H^{i}Scat as a sounding radar facility will be of great importance:

- Incoherent scatter studies of the ionosphere at much longer wavelengths and higher power than available with existing and planned radars (EISCAT VHF and UHF systems, Spitzbergen radar, STARE). These studies will provide information on the important small **k** vector regime.

- Radar sounding of the atmosphere and the lowest part of the ionosphere by means of standard MST techniques as well as the technique based on the enhancement of the atmospheric radar cross-section by acoustic irradiation.

- Solar and planetary radar applications with the possibility of, for instance, probing the solar atmosphere and deep into the lunar surface.

Nonlinear mode

The use of powerful ground-based HF facilities for controlled studies of nonlinear space plasma processes, in particular wave-wave and wave-particle interactions, has been an area of extremely rapid growth during the past decade. With such studies will be continued and expanded and the following research areas have been identified:

- Nonlinear sounding of the near-Earth plasma by means of new techniques developed in HF experiments over the last ten years. This includes studies of stimulated electromagnetic emission and artificial horizontal and field-aligned irregularities of the ionosphere. The possibility to work well above the critical frequency will make a new range of phenomena available for study.

- Sounding of the magnetosphere by using artificial ionospheric ELF/VLF sources created by wave mixing using two (or more) different transmission frequencies. Use of the technique with conjugately situated ground-based or satellite-borne equipment as developed in VLF nonlinear and VLF signal propagation experiments.

- Controlled initiation of large-scale auroral ionospheric and magnetospheric processes (substorms, Alfven maser processes).

Receiving mode

The sensitive and versatile antenna system for H^{i}Scat may very conveniently be used for radio planetary and astronomical applications (non-thermal radio emissions from astrophysical plasmas, low-frequency pulsar investigations in a low plasma density environment outside the galactic plane).

Technology mode

- The design and test phase of H^{i}Scat provides excellent opportunities for

- Full-scale antenna design studies and testing of innovative design ideas.

- Transmitter and receiver design.

- Development of new signal processing techniques.

In this work one can make use of the very latest achievements in electronics and computing technology.

Magnetospheric Physics

With H^{i}Scat, possibilities will for the first time be opened for detailed ground-based studies of the auroral magnetospheric plasma at altitudes which are out of reach for existing radars. This research area has been identified as one of primary interest, particularly because of the still unresolved questions concerning particle acceleration at auroral latitudes. For instance, the radar could be used to experimentally study the importance of such concepts as Alfven resonators and double layers.

The usage H^{i}Scatof for magnetospheric sounding is motivated by recently performed space-borne experiments on the S3-3 and Viking satellites which observed very strong turbulence in the magnetosphere of the auroral region at altitudes between 1000 and 13000 kilometers. The auroral magnetospheric turbulence is produced by several plasma instabilities such as ion-cyclotron and ion-acoustic instabilities and the generation of double layers due to strong field-aligned currents. This leads to the creation of anomalous resistivity regions along the geomagnetic field lines and produce strong parallel electric fields that accelerate particles, possibly causing such high-latitude auroral phenomena as auroral arcs in the lower ionosphere, ion conics and inverted *V* events in the magnetosphere. H^{i}Scat will provide new possibilities for the investigation of these phenomena, which except for a few cases can be studied directly only by satellites. Hence H^{i}Scat will be the first ground-based facility aimed at the direct probing of the high-latitude magnetosphere.

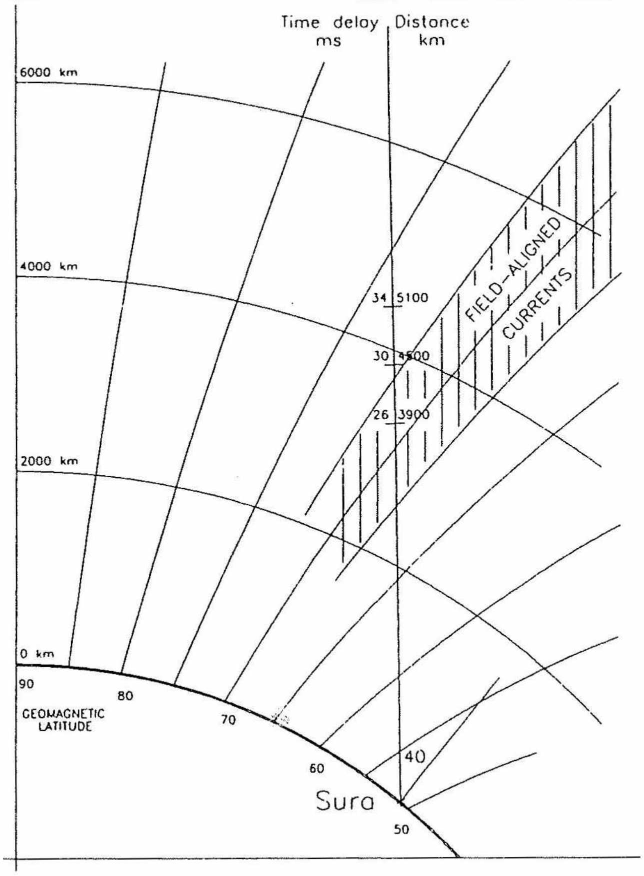

Figure 1. Geometry of the first magnetospheric turbulence scattering experiment at the Soviet RRI "Sura" facility near Nizhny Novgorod (Gor'ky).

H^{i}Scat can be operated together with the existing RRI "Sura" facility (geographical coordinates 56.13° N, 46.10° E), that has been used for the first magnetospheric scattering experiments. The steerability of the antenna beam will make it possible to probe the high-altitude magnetosphere over the Novaya Zemlya islands which is the present region of magnetospheric measurements with "Sura" in the frequency range 4.5–9 MHz. The proposed new "Sura" antenna array of frequency range 15–25 MHz will be designed to beam into the magnetosphere over northern Scandinavia and will therefore supplement the existing diagnostic facilities in this region. The cooperative usage of the H^{i}Scat and "Sura" facilities in both monostatic and bistatic modes will make possible the measurement of ion-acoustic waves with differently directed wave vectors **k** relative to the magnetic field lines. The angular range of **k** will be about 0° – 45° and will provide information on the distribution of the ion-acoustic turbulence in wave vector space. Coordinated measurements will also provide more accurate information of plasma motions in the auroral magnetosphere, double layers and geomagnetic pulsations.

By operating HiScat as a magnetospheric radar it should be possible to make the following measurements:

- Measurement of ion-acoustic turbulence and double layers at very high altitudes (several thousand kilometers). Example of ion-acoustic spectra, obtained by using the Soviet "Sura" HF modification facility (see Figure 1), are shown in Figure 2.
- Enhanced turbulence plasma line observations to estimate the electron density profile.
- Measurement of parallel plasma velocities and of perpendicular electric fields by using an inclined beam.

These continuous, "full-volume" measurements can be compared with discrete, single-point measurements from satellites as well as with other, supplementary instruments (rockets, radars, magnetometers, optical instruments).

For magnetospheric radar experiments with H^{i}Scat the following technical requirements must be fulfilled:

Pulsed operation.

- Wide frequency range for
  — Obtaining spectral and dispersive characteristics of the turbulence.
  — Use of very low probing frequencies to obtain maximum cross-section and highest possible altitude of sounding.
- Efficient reception of the scattered signals.
- Powerful computer techniques for data sampling and processing.

The difficulties one can foresee and should try to minimise are the following:

- The presence of strong zero-frequency signals caused by oblique ground clutter from all distances. These problems are more severe for low probing frequencies.
- Man-made noise at low frequencies (radio station interference and other noise). These problems are less severe for the high end of the frequency range and can be reduced by a careful choice of the location of the site.
- The stronger cosmic noise at lower frequencies.
- The scattering cross-section decrease with increasing frequency and altitude.

As is well-known, information on wave-particle interaction in the magnetosphere can be obtained by ELF and VLF probing. As an alternative to ground-based injection from ELF/VLF transmitters, as used in the experiments performed at the Siple station and its conjugate point Roberval, various modulation and frequency mixing techniques with can be used for ELF/VLF emission generation within the ionosphere. The use of for such ELF/VLF experiments requires that the individual transmitters and antennas can be operated on different frequencies simultaneously.

Ionospheric Physics

All scatter radars have one common and most important constraint. They are all dependent on scattering of the elec

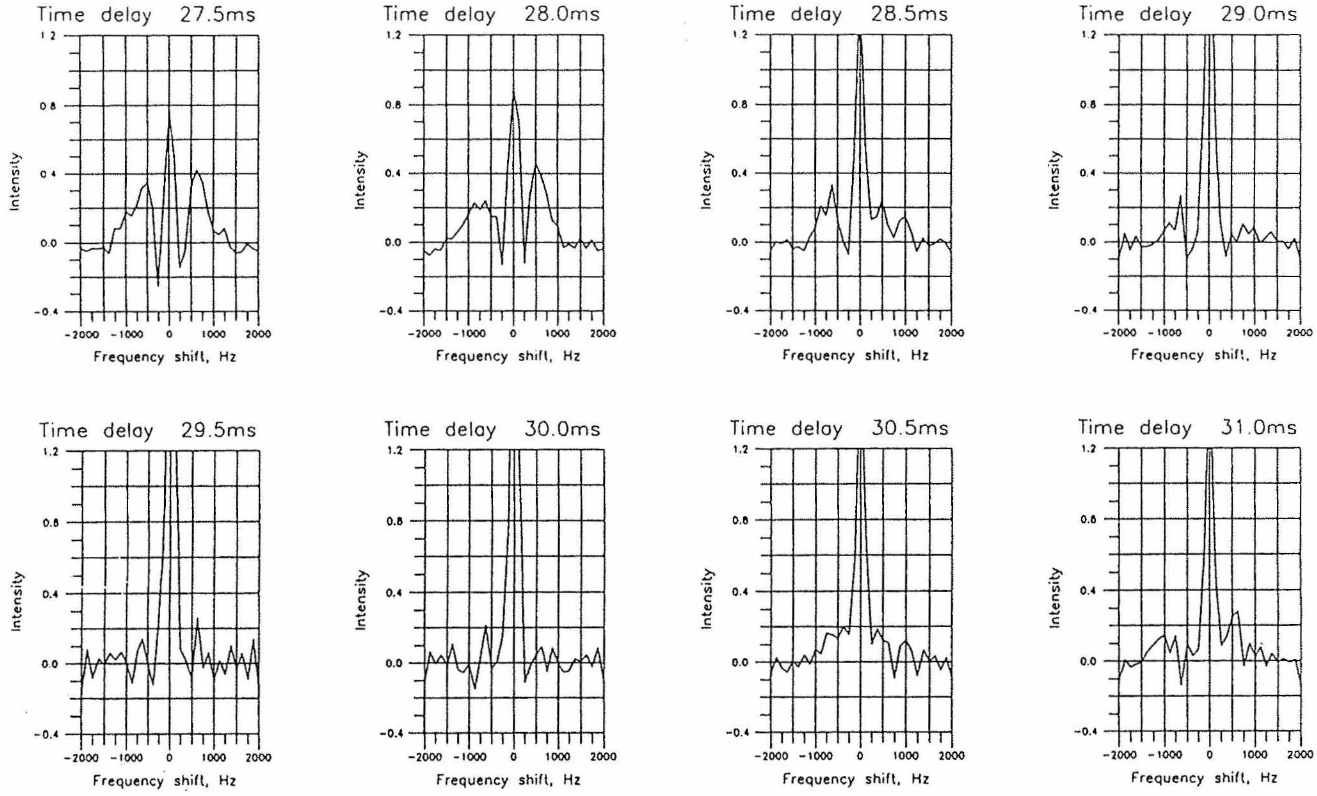

Figure 2. Magnetospheric scatter spectra obtained in the first magnetospheric turbulence scattering experiment at the Soviet RRI "Sura" facility. The symmetrical peaks, offset from the zero-frequency peaks in the first range gates, are due to scattering off ion-acoustic turbulence at about 4 000 altitude above Novaya Zemlya, USSR.

tromagnetic waves off structures with a spatial scale and orientation that match the radar wave vector (the Bragg condition). H^{i}Scat will be designed for operation in the 5–50 MHz range. When operated as an ionospheric incoherent (Thomson) scatter radar, H^{i}Scat will therefore provide information of wave numbers that are much smaller than are (and will be) possible with existing and planned auroral and polar zone radars. Hence H^{i}Scat will be a most useful addition to EISCAT which is operated at frequencies in the UHF (930 MHz) and VHF (220) MHz range. The technical requirements for these experiments are practically the same as for magnetospheric scatter experiments.

Nonlinear probing of the ionosphere will be utilised for ground-based measurements of parameters that cannot be determined with conventional linear diagnostic techniques. This can be done with the stimulated electromagnetic emission (SEE) technique, based on the analysis of the secondary electromagnetic radiation which is generated within a space plasma region pumped by the powerful H^{i}Scat wave. This secondary emission, which occurs at frequencies offset from the injected HF wave, was first discovered in ionospheric modification experiments in Tromsø in 1981 and has been observed in similar experiments at Arecibo, Puerto Rico, Fairbanks, Alaska, and Nizhny Novgorod/Gor'ky, USSR.

The SEE technique allows very accurate nonlinear diagnostic of the near-Earth plasma. For instance:

- As discovered in joint Swedish/Soviet experiments in 1990, the stimulated electromagnetic emission (SEE) spectra dramatically change their characteristics over a very narrow range of pump frequencies as a result of cyclotron damping. With this technique it is possible to determine the local ionospheric electron cyclotron frequency at the upper hybrid layer with an accuracy of a few tens of Hz and hence the local magnetic field strength with an accuracy of better than 1 nT.

- Operation at two slightly separated HF frequencies will give rise to parametric mixing and electromagnetic emissions of extreme narrowness suitable for the accurate study of bulk plasma motions by Doppler analysis.

Another technique, developed at RRI, is based on the creation of artificial periodic irregularities in horizontal strata in the ionosphere below the reflection point of the powerful HF wave. The irregularities are established by the powerful HF wave and are probed with another HF wave of opposite wave polarisation and different frequency. This technique provides new methods for ionospheric plasma investigations:

- Measurement of the plasma density profile of the ionosphere, also in the "valley" between the and layers, with a resolution that is comparable to that achieved in rocket experiments.

- Measurement of vertical movements of the ionosphere with velocities of a few tens of centimetres per second.

- The determination of some natural ionospheric parameters such as electron and ion temperatures, ion-neutral collision frequencies and coefficients related to collisions in the layer.

There are several new possibilities for lower ionosphere diagnostics when H^{i}Scat is used in one of the modes for producing a controllable ionospheric ELF/VLF antenna:

- The monitoring of mesospheric processes by means of long-term VLF measurements. As has been shown earlier there is a direct connection between variations in the Stokes wave polarisation parameters of the VLF signal with mesospheric turbulence and internal gravity waves. In particular it should be emphasised that VLF measurements are ideally combined with H^{i}Scat operation in MST mode to provide maximum information of mesospheric phenomena.

- The possibility to use the ionospheric ELF/VLF antenna to control the propagational constants of the Earth-ionosphere waveguide and the electromagnetic boundary conditions in this frequency range.

- The exploitation of the high latitude location for the H^{i}Scat facility. As has been shown in Tromsø experiments the capacity to steer the antenna beam will provide unique methods for investigations of the fine structure of the polar electrojet.

To make full use of the ELF/VLF generation mode of it will be desirable to have several VLF receiving points:

- One receiver immediately below the ionospheric ELF/VLF antenna.

- Two or three additional receivers in the radiation zone, with one near Luleå,

- one in Uppsala, in the south direction, and

- one at Apatity, in the east direction.

H^{i}Scat will be designed for the optimal use of the SEE technique. The important point here is to be able to operate at high powers and relatively low frequencies, below or above the ionospheric critical frequency. The ELF/VLF experiments do not require any special H^{i}Scat design considerations other than high power and good frequency and antenna beam agility.

Atmospheric Physics

There is currently a great interest in the physics of the Earth's middle atmosphere (generally taken to be the altitude region 10–100 km) manifested by the international cooperative Middle Atmosphere Program (MAP). There exists a region between those altitudes that can be reached by aircraft or high-altitude balloons ($\approx$ 30 km) and the very high altitudes surveyed by spacecraft where possible techniques for remote sensing are particularly important for providing measurements of geophysical parameters.

The term MST radar is used for systems that make use of the very small coherently scattered radiation from small-scale irregularities in the refractive index of the neutral atmosphere (the mesosphere, stratosphere, and troposphere) to study the dynamics and structure of the middle atmosphere. The use of such radars has spread rapidly during recent years. New installations have been constructed (in Germany the SOUSY radar, in Japan the MU radar) and existing installations built for other purposes are also employed (in Scandinavia and the polar region, EISCAT and Søndre Strøm). There is need for additional systems with new characteristics or at different geographical locations, especially at high latitudes, in order to establish a more complete MST radar coverage.

All existing facilities work at a fixed frequency of 40–50 MHz or, in some cases, much higher frequency. A new dimension in MST studies with H^{i}Scat will be the multi-frequency capability which, literally, exploits a new regime in wave number space as any radar probes only scale sizes of the refractive index which corresponds to half the radar wavelength. The steerable beam of H^{i}Scat provides additional advantages in the MST work.

The association of H^{i}Scat with the Esrange rocket range will provide a unique opportunity for correlated measurements in situ throughout the middle atmosphere height range 10–100 km.

Basic Space Plasma Physics

Even though H^{i}Scat is designed primarily to probe naturally occurring plasma phenomena in the auroral magnetosphere and ionosphere it is possible to use this environment as a giant plasma laboratory without walls with the principal goal of investigating fundamental linear and nonlinear space plasma physics. With its high power and wide frequency range, H^{i}Scat facilitates such fundamental studies, aimed at the development of new diagnostic techniques as well as "model experiments" in the near-Earth space plasma laboratory. In a way, this is a new approach in space plasma physics where one traditionally only makes passive observations of phenomena that Nature creates in a more or less uncontrolled way at unpredictable times. Instead, in the "space laboratory" experiments, one studies the effects of controlled perturbations in a stimulus/response fashion in much the same way as in a traditional physics laboratory. This novel technique enables the investigation of dynamic processes in space plasmas in order to better understand basic linear and nonlinear wave phenomena — not only in the near-Earth plasma but also in the solar and stellar atmospheres.

Astrophysics

After discussions with US astronomers (Jim Cordes, Cornell University, Tim Hankins, Dartmouth College, Dan Stinebring, Princeton University, Alex Wolszczan, Arecibo Observatory) it has become clear that there is a considerable interest in radio astronomy observations from high-latitude radio observatories. One reason for this is that, for a given antenna beam steerability, an astrophysical object may be observed for a longer uninterrupted period at high latitudes than at low ones. Also, radio astronomy in densely populated areas is often plagued by interference from various radio and TV stations. Such interference may be much less severe in an area like northern Scandinavia where the population density is low. It is therefore believed that H^iScat, with its large antenna collecting area, could be very useful for radio astronomy in general and pulsar work in particular.

One new trend in pulsar radio astronomy has been towards lower frequencies. At Arecibo Observatory, Puerto Rico, the receiving system for the 50 MHz radar has been used for pulsar work. Also, interesting observations, obtained at 10 MHz, have been reported from the Soviet Union. Whereas most pulsars are located in the galactic plane, it is well-known through searches carried out at various observatories that many pulsars are located also outside this plane and therefore may be observable by H^iScat. Since the H^iScat observation frequencies will be low, this is an advantage because the galactic plane contains more plasma and hence gives rise to stronger dispersion and scattering of the pulses, a problem which becomes more accentuated at lower frequencies. With its position near the trough region, where the ionosphere is sometimes almost transparent (low total plasma content and low absorption), H^iScat will be useful to the radio astronomer interested in low frequency observations of galactic and extragalactic objects.

Scientifically, it is thought that low-frequency observations will provide information which will have substantial implication for pulsar models. Reports from 10 MHz observations in the USSR, claiming the detection of an intriguing interpulse structure, is one example of this. Another example is the wave polarisation which at low frequencies is thought to yield information on the outer magnetospheres of the pulsars. Also, comparative measurements of pulsar timing between low and high frequencies will be a very useful way to probe the interstellar and interplanetary plasma. Furthermore, observation of the interstellar scintillation of pulsars at low frequencies would provide excellent opportunities to study the small scale structure of the local interstellar plasma.

Other strong astrophysical radio sources of interest to study are active galactic nuclei (AGNs; e.g., quasars, Seyfert galaxies). While these have been studied at higher frequencies very little work has been done at lower frequencies. Here H^iScat may prove to be very useful indeed. AGNs emit incoherent electron synchrotron radiation at frequencies $\geq$ 300 MHz. Low frequency observations would probe the presence of coherent emission (analogous to pulsar, Jovian, and terrestrial emissions) and therefore may strongly constrain relativistic beam models that have been proposed.

The technical requirements for H^iScat would be a large antenna system that can produce a well collimated steerable beam. The steerability of the proposed H^iScat antenna of at least ± 40° from zero position can be considered very good. Another requirement for radio astronomy would be a very precise timing system (typically 1 μs) and extensive communications facilities for coordinating simultaneous measurements at H^iScat and other observatories.

Further Possibilities

The above mentioned list of experimental uses of is far from exhaustive. In order to investigate further possibilities, a large number of -related studies are being undertaken. What follows is a brief presentation of the work going on at the Radiophysical Research Institute (RRI) and Applied Physics Institute (API), Nizhny Novgorod/Gor'ky, with support from the Lebedev Institute (LI), Moscow, USSR, as well as at the Swedish Institute of Space Physics, Uppsala Division (IRFU) and Kiruna Division (IRFK), Sweden. The conclusions from these studies will be included in the forthcoming H^iScat feasibility study and will underline the wide range of opportunities for new and improved experiments.

Radar and scattering applications

1. Magnetospheric sounding, (A. N. Karashtin, RRI, A. V. Gurevich, LI).
2. Incoherent scatter, (B. Thide, IRFU).
3. MST radar, partial reflection, and artificial horizontal periodic irregularities applications (V. V. Belikovich, E. A. Benediktov, V. D. Vyakhirev, N. P. Goncharov, RRI).
4. Radio acoustic sounding (V. A. Zinichev, RRI).
5. Radar investigations of the Moon, Sun and planets (Yu. V. Tokarev, RRI).

Nonlinear space plasma applications

1. Stimulated electromagnetic emissions (B. Thide, S. Goodman, M. Waldenvik, IRFU, T. Leyser, IRFK, S. M. Grach, V. L. Frolov, RRI).
2. Initiation of substorm phenomena (V. Yu. Trakhtengertz, API).
3. Additional ionisation during powerful heating by a focused HF radio beam in the atmosphere and lowest layers of the ionosphere (N. D. Borisov, IZMIRAN, A. V. Gurevich, LI).
4. Combinational frequency generation to be used as a tool for ELF/VLF magnetospheric sounding and studying wave-particle interaction phenomena (D. S. Kotik, RRI).
5. Artificial ionospheric turbulence, strong turbulence, particle acceleration (V. Yu. Trakhtengertz, API, L. M. Erukhimov, S. M. Grach, N. A. Mityakov, RRI).
6. Generation of low frequency electromagnetic radiation by modulation of ionospheric currents through HF heating for monitoring mesospheric processes and ionospheric boundary layer conditions (D. S. Kotik, S. V. Polyakov, V. O. Rapoport, RRI).

7. Cherenkov excitation of VLF radiation in the ionosphere by means of HF beam motion at superluminous speed—possibilities for lower ionosphere diagnostics (L. F. Mironenko, RRI).

8. Excitation of ionospheric and magnetospheric MHD resonances: Alfven maser effect (V. Yu. Trakhtengertz, API, S. V. Polyakov, P. P. Belyaev, RRI).

9. Mean heating and related effects (Yu. A. Ignat'ev, RRI).

Antenna design applications

A preliminary, innovative antenna design has been worked out in the USSR (I. F. Belov, V. V. Bychkov, D. S. Kotik, RRI). This work is continued and supported by advanced computer analysis in Sweden (B. Thide, E. Veszelei, IRFU).

Radio astronomical applications

Studies of radio astronomical applications are carried out in the USSR (Yu. V. Tokarev, RRI) and supplement earlier, preliminary discussions between Swedish and US scientists.

Technology and Hardware

In a facility of this type, which is aimed for operation well into the 2000s, it is essential to adopt a design strategy that will provide maximum versatility, incorporating the latest technology and simple upgrade paths. It is therefore suggested that H^{i}Scat be highly modular and built in such a way that all experiments can be run completely "in software". This includes not only the traditional digital control of transmission pulse schemes and the signal analysis, but also the forming of the transmission and reception radio beams. A sufficiently large phased array antenna, where each antenna or a group of very few antennas is connected to individual transmitters and receivers, will enable the forming of different types of transmitted beams, including the focusing of the energy into a thin layer, and multichannel digital recording of the received signal allowing after-the-fact forming of the receiving antenna beam.

Location

Because of the relatively mild climate and the well developed scientific and logistic infrastructure, northern Scandinavia is the most convenient geographical location for H^{i}Scat. In this region, the Kiruna area seems to be optimal. This area provides easy access to supplementary ground-based diagnostic facilities and also to the Esrange rocket range and satellite ground stations. On the spot inspection has given good hope of finding a suitable location either north east or south west of the Esrange launch area, with access roads and high power electricity very close to the site. Further surveys from land and by helicopter are in progress and the selection of a few possible sites is expected within the next few months. The conjugate point of Esrange (geographical coordinates 68.0° N, 20.5° E) is about 60.0° S, 63.0° E. Whether it is possible to operate a ground station at this conjugate point is still being investigated. Such a station would be very useful for the magnetospheric ELF/VLF experiments.

Antenna system

One of the basic design ideas for H^{i}Scat is to combine many uses and operational modes into one and the same facility. This requires that the antenna should be of a fairly general design with good gain, frequency bandwidth and steerability. Studies showed that no existing scatter radar or HF modification antenna fulfilled all these requirements. Therefore, a new type of optimised phased array antenna has been invented at RRI. It is clear that this antenna, which is in its final stage of design, will be able to fulfil virtually all the requirements of H^{i}Scat. The main design concept is to arrange the individual antenna elements at judiciously chosen positions within the structure to provide maximum forward gain with a minimum number of elements. The bandwidth is 5–50 MHz and the steerability is at least from zenith. With an antenna system diameter of less than 1 km, the gain will be about 40 dB at the highest frequency edge (50 MHz) and about 30 dB at the lowest edge (5 MHz). Theoretical analysis of a simplified model of the proposed antenna has shown that by focusing it should be possible to increase the gain even further to create localised "hot spots" with very high field strength. The actual design of the antenna will be presented at a later stage, after a formal patent application has been filed.

A full-scale RRI antenna array, with a limited number of elements, will be built remotely from the H^{i}Scat site, probably near the EISCAT ground station outside Kiruna. This antenna will be used for design tests and verification but will also be useful for "classical" SEE work, where it is essential to be able to perform analysis of very weak emissions during the HF transmission, and for interferometry with a long baseline (approximately 30 km in the east-west direction).

The high performance aimed at can be achieved with a cluster of antenna/receiver combinations and a very efficient data-taking system recording amplitude and phase from each individual receiver/antenna subelement. In this way, the reception beam can be constructed in software after the actual data taking. There is also a possibility to use optical beam forming techniques where one "transforms" the HF frequency into the laser frequency regime. The so-formed laser beam is then operated on with optical lenses and similar devices, and then transformed back into the HF regime. It seems that this is a very useful technique that is easy to use and would be ideal for forming the transmitted beam. Presently, discussions regarding the optical beam forming concept for is going on with the MBB company in Germany.

In radio astronomy, the system sensitivity, , is most conveniently measured in Kelvin (K) per Jansky (Jy = 10^{26} W/m^2/Hz), defined as $S = 10^{-26} EA/\kappa$ K/Jy, where is E the system efficiency coefficient, A the antenna collecting area, and κ Boltzmann's constant. Hence, for a system efficiency $E = 1/2$, unity sensitivity S corresponds to an antenna area of $A = 2760$ m^2. With an assumed efficiency $E = 1/2$, the H^{i}Scat antenna with 280 000 m^2 collecting area would yield a sensitivity of about 100 K/Jy, an excellent figure.

Transmitter configuration

To fulfil the H^{i}Scat design goals it does not seem possible to use the conventional design with a few very high power tube transmitters. Instead, it seems more appropriate to use a large number of compact solid state final amplifiers, connected to individual antennas or groups of antennas. Using standard, inexpensive transistorised amplifiers run in class *AB* for linear operation (when modulation is used) or in class *C* (for CW and pulsed operation) it should be possible to achieve a maximum output of a few kW from each such amplifier. Using a few hundred such amplifiers, fed at a low drive level to minimise transmission line costs, the total output power would be 1 MW or more. With 40 dB antenna gain this would produce an effective radiated power (ERP) of more than 10 GW in the upper part of the frequency range and about 1 GW in the lower part of the frequency range where the antenna gain is about 30 dB. This would be adequate for most of the experiments described in this status report. The modular and scalable design chosen for the antenna and transmitter configuration will allow a gradual upgrade of H^{i}Scat to even higher levels of ERP, should that prove desirable.

Receiver system

The receiver system will consist of a certain number of individual receivers with I/Q detection connected to groups of antennas so as to provide enough amplitude and phase data for construction of the reception beam in software. The exact number of receivers will be determined once the antenna design is complete and the beam angular resolution has been agreed upon. Currently, the possibilities for a modular hybrid block design of the receivers based on the design principles developed for the Uppsala SEE detector system is being investigated. Such a design would simplify the actual construction and probably minimise the cost.

Control system

H^{i}Scat will be operated fully in software. With a standard ised computer system and software, preferably a UNIX workstation environment, the experimenter can use well known software tools to write his own control and data taking software. With the remote control capability and connections to standard worldwide computer networks, which are now available at most universities, it should be possible to ultimately run many of the experiments from the experimenter's home institution. The proximity to Esrange will provide opportunities to use satellite links for data exchange.

Estimated Costs and Funding

Before the final design of has been agreed upon it is very difficult to estimate the total cost. A crude analysis points to a total final cost of somewhere between SEK 70 000 000 and SEK 100 000 000 (about USD 10 000 000 to 15 000 000) but the modular design of H^{i}Scat will permit an initial, limited capability H^{i}Scat facility to be built at a considerably lower cost.

An important contribution to the funding will be the antenna system which most likely will be designed and built by RRI with Soviet funding. Further negotiations in this matter are underway. For several years now the Swedish Natural Science Research Council (NFR) has considered H^{i}Scat as a future "big science" project. However, it is clear that the magnitude of the complete H^{i}Scat project calls for extended international support, both scientifically and financially, and such support is now being sought on a world-wide basis.

Bo Thide and **Rolf Bostrom** Swedish Institute of Space Physics, Uppsala, Sweden

Anatolij N. Karashtin and **Dmitrij S. Kotik** Radiophysical Research Institute, Nizhny Novgorod (Gor'ky), USSR

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THE EDITOR'S "PAGE" (continued from page 95)

Unlike some other ISU's, the URSI membership level is up to the member (meaning the subscription payer) to decide for itself. If there is no economic or political advantage, the payer will want to pay the rate for the lowest level.

Some other ISU's or ICSU Special Committees like SCAR and COSPAR have much higher membership fees and membership because the various countries find it prestigious or politically or economically advantageous to be members. I haven't done the research but I gather that URSI was once the body where decisions were made (like spectrum use) which politicians — and not just us radioscientists — felt were important enough to require their country's representation.

Distasteful as it may be, and it is to me, I think URSI has to respond by becoming more market oriented and by providing "benefits" (of the sort which market economists would recognise) for members and which are denied non-members. Maybe such benefits exist of which I am ignorant. The needs of URSI members at the low end of the GNP spectrum, and the fees they have to pay, need to be looked at carefully because they are the ones most at risk.

I haven't offered any solutions and I have raised contentious issues and problems. It is my opinion that URSI needs to respond and not ignore these issues. So let the URSI community share your suggestions and opinions as *Letters* in the next issue (by 1 February, 1992, please).

FEATURE ARTICLE

Thirty Years of Upper Atmosphere Research at Rhodes

PART I: by J. A. Gledhill

The beginning

It was late in 1960 that Cyrol Hide, of the CSIR, visited Rhodes University and asked me if I was interested in doing ionosphere research in Antarctica. I commented that it was not a very attractive prospect, because the place was too far away for guidance of the man in charge of the field work to be effective, and it was also very cold especially in winter. But when he pointed out that South Africa, as one of the twelve signatories of the Antarctic Treaty, was required to establish presence on that remote continent, and that funding could be expected to be on a considerably more adequate scale than that generally available for home-based projects at that time, I said at once, 'Oh, well, in that case I'm interested.' 'Do you know any student who might be prepared to go at the end of next year?' he asked. I looked at my watch and saw that it was time for tea. In the tearoom I asked the students if anyone was interested. At once Duncan Baker responded: 'Yes, I've always wanted to go to Antarctica!' So began the research programme that has continued through the past quarter of a century.

It was not as easy as at first appeared. There was a lot of red tape to be cut and tied before Baker was officially appointed as an expedition member. It was in fact October 1981 before this was confirmed. We had in the meantime decided to take the risk and give him experience in the operation and maintenance of the *sine qua non* of ionosphere research, an ionosonde. This is a specialized variable-frequency radar that is used to measure heights of the different ionized layers in the upper atmosphere, called the ionosphere. We were lucky to be offered the loan of a Cossor ionosonde that had been operated for a short time during the International Geophysical Year (IGY) (1957-58) on Marion Island by the National Institute for Telecommunications Research (NITR) of the CSIR. First, this had to be brought back to South Africa, then it got lost for a time in transit in Johannesburg from the coast; finally we were able to send Baker up to the NITR to give it a thorough overhaul, learning how it worked, and how to keep it in working order, as he did so. He left South Africa with the third South African National Antarctic Expedition (SANAE 3) early in January 1962 (Figure 1).

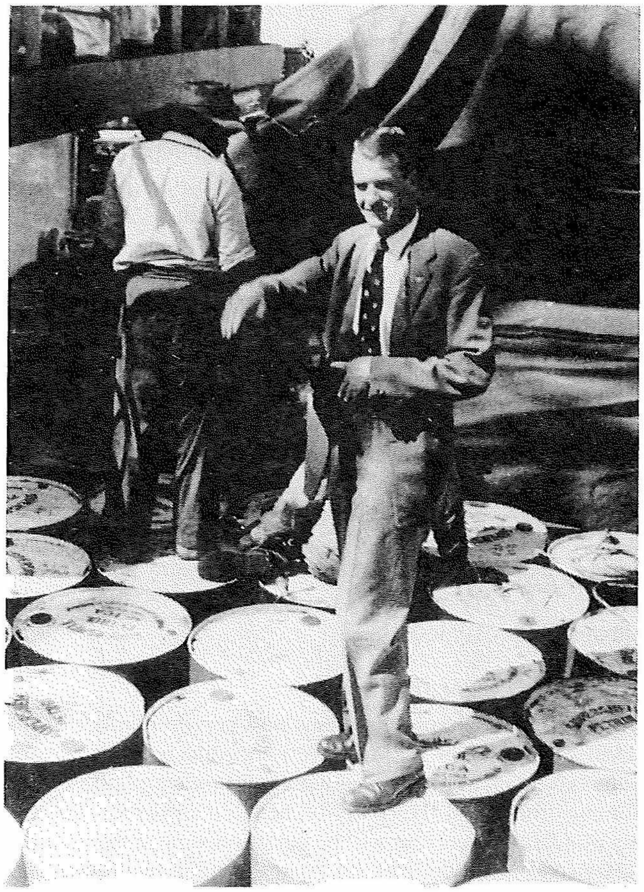

Fig. 1. Duncan Baker on board the RSA before leaving Cape Town for SANAE, January 1962.

Ionograms

The expedition members had to set up their base on arrival in Antarctica and it was May before Baker let us know by radio that he had successfully recorded his first ionogram on photographic film. An ionogram (Figure 2) is a record showing the time it takes radio waves to travel to the point in the ionosphere at which they are reflected, and back to the earth's surface. The higher the frequency of the radio waves, the greater is the number of free electrons per unit volume needed to reflect them. Since this 'electron density' increases with height in the atmosphere, higher frequency waves travel to greater heights before reflection, and thus return a little later than those of lower frequency. At the lower end of the scale on the ionogram in Figure2 the radio frequency is about 0.6 MHz, and it increases towards the right to values of about 15 MHz. In Figure 2 there is no reflected signal below 2.6 MHz, due to absorption of the radio waves in the lower part of the ionosphere, the D-region, at 70–100 km. At 2.6 MHz a reflected signal is seen at a delay corresponding to an apparent height of 100 km, from the E-region, the apparent or 'virtual height' is calculated on the assumption that the radio signals travel with their free-space speed on their journey to and fro; in fact, they are slowed down in the ionospheric plasma and allowance must be made for this to find the true height at which they were reflected, and hence the electron density as a function of height.

At about 4.4 MHz the waves penetrate the E-region (Figure 2). This is referred to as the 'critical frequency' of the E-region for the ordinary ray, foE. Examination of the ionogram shows that there are in fact two traces – this is obvious at greater frequencies in Figure 2. This is due to an effect of the earth's magnetic field, which causes the plasma to be birefringent. The trace with the lower critical frequency is the ordinary ray, the other one the extraordinary ray. Above 4.4 MHz the signal is returned from the higher F1-region; in Figure 2 its minimum virtual height is 210 km. At 6.3 MHz this region is penetrated by the ordinary ray (foF1) and the signal then returns from the F2-region,

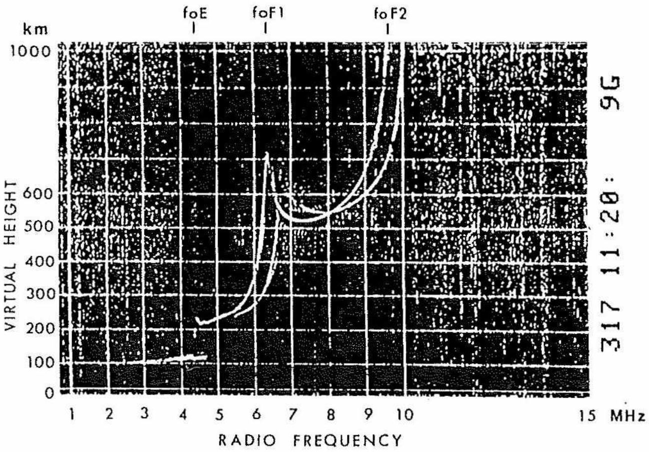

Fig. 2. A typical ionogram (see text).

which shows a minimum virtual height of 515 km (the actual height of reflection of these waves is much lower than this, because of the slowing down referred to above). Finally, above 9.6 MHz (foF2) the radio signals escape into space, there being no denser layer above the F2-region to reflect them. Thus, by a careful study of ionograms and some computation, it is possible to deduce the distribution of free electrons in height from the E-region to the maximum of the F2-region.

The electrons concerned are set free from their parent atoms and molecules by the sun's ultraviolet light and also by incoming energetic electrons from space, as happens in the auroras. Since the solar ultraviolet radiation is cut off from the ionosphere by the earth's shadow for a large part of every 24 hours during the polar winter, there is considerable interest in finding out what happens to the ionosphere there at that time.

An interesting effect observed by Baker at SANAE, the Antarctic base, was a total ionospheric black-out (i.e. no reflections observed from the ionosphere at any frequency), which we later found to coincide with the explosion of a high-altitude nuclear device in the USSR. This was one of the earliest observations of the ionospheric effects of the high-energy particles released during the explosion of a nuclear bomb at high altitude.[1]

Anomalous daily variation at SANAE

By the beginning of 1962, the planning of South African Antarctic expeditions was much improved and it was possible to appoint D.G.Torr as Ionosphere Physicist in time to give him a much more thorough introduction to the techniques involved than Baker had received. He took over the ionosphere programme at SANAE at the beginning of 1963 as a member of SANAE 4, while Baker returned and promptly got married. From the year's ionograms he brought back we were quickly able to establish that SANAE was one of a group of stations, all in the Weddell Sea area, that show an anomalous behaviour in summer.[2] At the vast majority of stations throughout the world, the maximum number of free electrons per unit volume in the ionosphere above about 200 km, the F-region, increases to a maximum an hour or two after noon and then falls again, on the average, as shown by the Grahamstown plot in

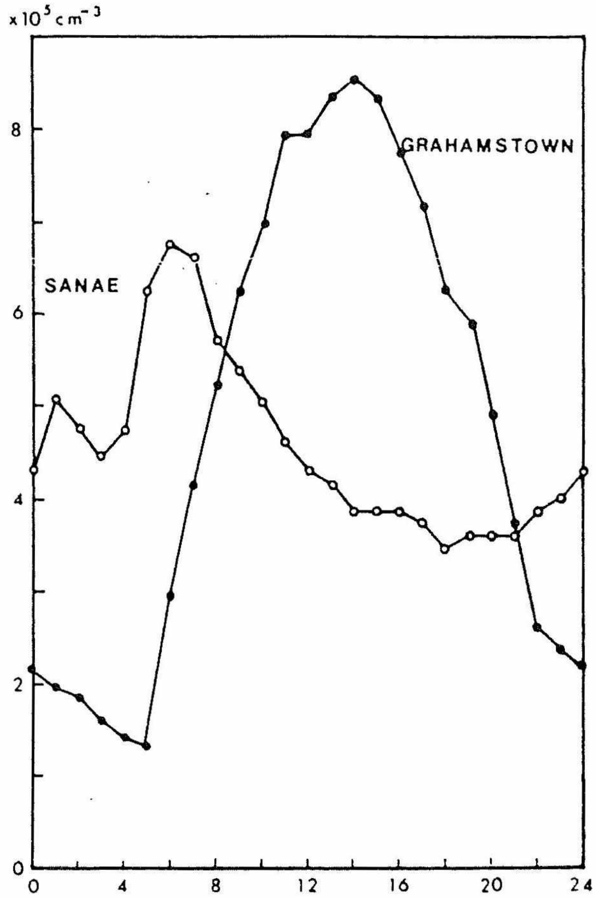

Fig. 3. Comparison of the mean daily variation of the maximum electron density in the F2-region for January 1978 at Grahamstown and SANAE.

Figure 3. This is because the electrons are detached from their parent atoms or molecules of oxygen and nitrogen by the ultraviolet rays of the sun. Near noon, when it is most nearly overhead, the rate of ionization is greatest and this leads to the midday maximum in electron number density. At the Weddell Sea stations of Argentine Islands, Halley Bay and Ellsworth it had been shown during the IGY that, during the summer months of November to February, the maximum electron density in the F-region occurred at about 06 UT, with a minimum at about 18 UT. We had now shown that SANAE was one of this group, the most easterly yet found. Figure 3 illustrates this by comparing the average daily variation of the maximum electron density in the F2-region at SANAE and Grahamstown during January 1978. Grahamstown shows the typical mid-latitude daily change, with the maximum at 14 h local time and the minimum just before sunrise at 05 h, whereas at SANAE the maximum occurs at 06 h local time (which is also UT) and the minimum at 18 h.

The explanation of this puzzling phenomenon was given some years later by J.W.King, at one time a member of the Rhodes group, but then working at the DSIR Radio and Space Research Station at Slough, England, with H.Kohl, of the Max Planck Institute for Aeronomy, Lindau-Harz, Germany.[3,4] They pointed out that the heating of the upper atmosphere by the sun's rays in the region beneath the sun (near the sub-solar point) causes the atmospheric gas to expand, and this in turn causes winds to blow in all directions round the earth towards the midnight region, where the temperature and pressure are at a minimum. The part of this wind that blows over the South Pole causes the ionized gas in the F-region of the ionosphere in the Weddell Sea area to move up the lines of force of the earth's magnetic field there, since the ions can move easily along the magnetic field direction but not across it, as they would have to if they were blown horizontally by the wind. This causes the F-region to move upward, reaching a maximum height at about 06 UT. At this higher level recombination of the electrons is slower, because of the more rarefied atmosphere at the greater height, and so there are more free electrons than there would have been with no such wind. Near 18 UT, on the other hand, the ionized gas is blown down the lines of force to lower levels, where recombination is quicker in the denser atmosphere, and a minimum in the electron density results. This does not take place in other parts of Antarctica because the south geomagnetic pole is displaced from the geographic pole towards New Zealand. In consequence of this, the geometry of the winds and the magnetic field is such as to produce the 06 UT maximum and the 18 UT minimum only in the South Atlantic region of the globe. In winter, with the sun below the horizon most of the time, there is not enough ionized gas to show the effect. M.H.Williams (SANAE 9) made a detailed analysis of this explanation on his return to South Africa and found that, although the overall theory was in reasonable accord with the observations, there remained a lot of variation which demanded further study and elucidation.[5,6]

Particle precipitation

The Russian satellite group under S.N.Vernov and V.L.Ginzburg had shown in 1961 that, because of the displacement of the geomagnetic pole from the rotational one and the tilt of the magnetic axis that caused it, the protons and electrons trapped in the earth's magnetic field in the Van Allen radiation belts penetrated right down into the F-region of the ionosphere over the South Atlantic, with two regions of maximum intensity, one between South Africa and Brazil and the other between South Africa and Antarctica. Figure 4, which is compiled with data from Ginzburg *et al*,[7] shows these regions quite clearly. We at once realized that there was a unique phenomenon on our own doorstep, with the 'Southern Anomaly' conveniently situated between Grahamstown and SANAE. D.Torr who had been appointed to a new research assistantship funded by the Antarctic programme of the Department of Transport, decided to make a special study of the effects of this unique bombardment of the ionosphere by charged particles and used his records of ionospheric behaviour, made at SANAE, for this purpose. We had in the meantime made contact with Dr I.B.McDiarmid, who was observing these precipitating particles above the ionosphere from the Canadian satellite Alouette I. Some time after Torr's return we were able to show that there was a one-to-one correspondence between high fluxes of precipitating electrons with energies above 40 keV observed by Alouette I near SANAE and disturbed conditions in the F-region at SANAE.[8] Not only that, but it appeared that SANAE showed a greater percentage of such disturbances than any other station for which data were available, as we had originally expected on the basis of the Russian maps of the regions of such particle precipitation[9] (Figure 4).

The next phase of this work should obviously be to attempt a more quantitative explanation of the ionospheric effects of these particles. This was impeded by several factors. The particle detectors on Alouette I and other satellites flying at that time did not measure the fluxes of electrons at energies below 40 keV, which were of the greatest importance in affecting the ionospheric E and F regions; the theory of the interaction of energetic electrons with the neutral atmospheric gases was in an early stage of development; and the ionosonde at SANAE, originally bought in 1956 for use at Marion Island during the IGY, began to show its age and more and more records were being lost through equipment problems. Nevertheless, regular bulletins of ionospheric characteristics at SANAE were produced and circulated to world data centres in the USA, USSR and Japan, and to more than 30 other interested institutions throughout the world. In this way, as well as by papers presented at international conferences, the work at SANAE became well-known internationally.

New ionosondes

Meanwhile the organization and administration of Antarctic scientific research in South Africa was progressively improved and put on a sounder financial basis, so that it eventually became possible to order two much more sophisticated ionosondes made by Barry Research Inc. in California. These instruments operate on a novel principle. Instead of sending out a short 60 – 100 μs) pulse of radio waves and timing its return, as in conventional radars and ionosondes, the Barry instrument transmits a continuous wave, the frequency of which is gradually increased at a very accurately controlled rate, typically 50 kHz per second. When the signal returns after reflection by the ionosphere it normally still has the same frequency as when it was transmitted. Typically, it takes about 2 ms for a signal to travel up to the F-region, be reflected there and then to come back to the transmitting site. In this time, the frequency of the transmitted signal will have increased by 2/1000 of 50 000 Hz, i.e. 100 Hz. Thus if the returned signal is mixed with the frequency now being transmitted, a difference frequency of about 100 Hz will be detectable, the frequency of which is proportional to the time delay of the reflected signal. From this the virtual height of reflection can be calculated and hence the distribution in height of the electron number density. The ionogram shown in Figure 2 was made by this technique.

Oblique incidence ionograms

We took a carefully evaluated risk in deciding to use this type of ionosonde at SANAE. Few were in use anywhere in the world at that time and no-one had operated such a sophisticated device under the demanding conditions of the Antarctic. Nevertheless, our faith has been completely justified. With two such ionosondes, one at SANAE and the other at Grahamstown, it became possible to record complete incidence ionograms over the range 2-30 MHz from SANAE to Grahamstown. These radio waves pass through the region where the Russian Sputnik 5, and other satellites since, observed the precipitation of electrons from the magnetosphere into the ionosphere (Figure 4), and so offer a unique opportunity to study phenomena there. Unfortunately this aspect of the programme has been severely limited by lack of manpower and only a prelimi

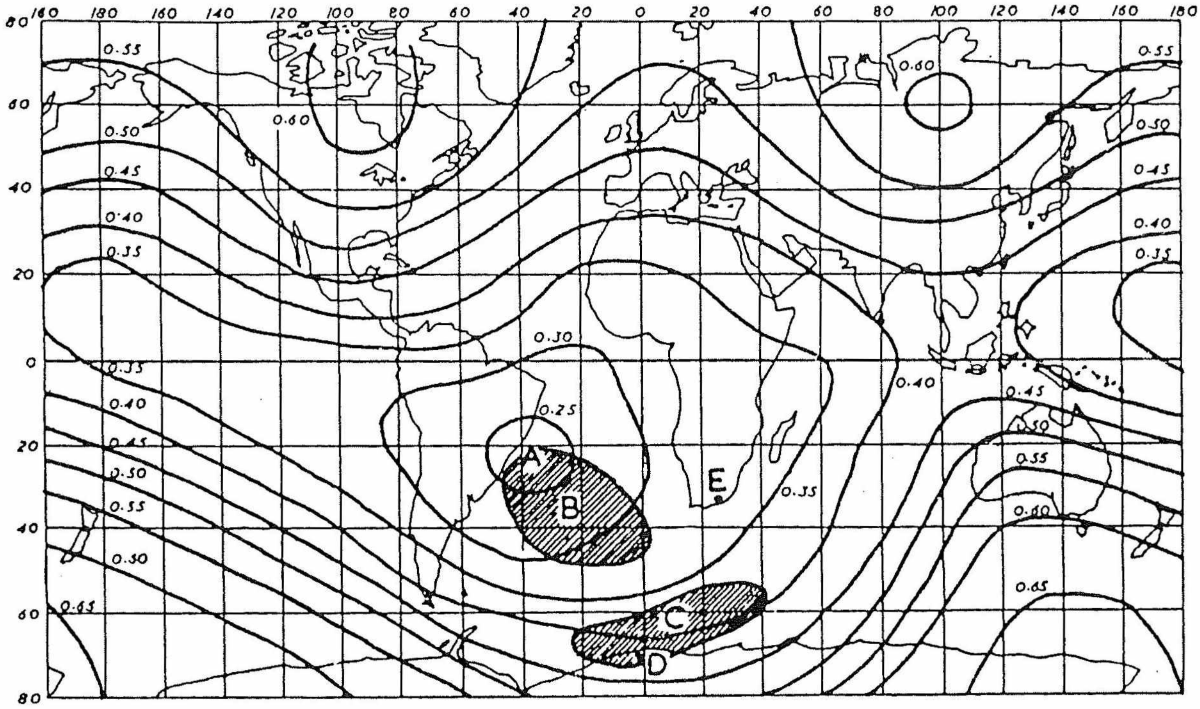

Fig. 4. Map showing lines of equal intensity of the Earth's magnetic field (in gauss). *A* Point of minimum intensity on the surface. *B* Region of high intensity of energetic particle bombardment observed at about 200 km height by Ginzburg *et al.*[7] and named by them the South Atlantic Radiation Anomaly. *C* Region of high intensity bombardment named the Southern Radiation Anomaly by Ginzburg *et al.*[7] *D* SANAE *E* Grahamstown. The 'South Atlantic Anomaly' or 'Brazilian Anomaly' is generally thought of as being the region bounded by the 0.3 gauss contour on the map.

nary study has been made of the thousands of oblique incidence ionograms available.[10,12]

Despite its lack of depth, many exciting things have emerged from this study. We were able to observe large-scale waves propagating in the ionosphere from SANAE toward South Africa on several occasions[12] and we were able to show that the condition of the ionosphere near the Antarctic end of the link normally, though not invariably, controls the frequencies that get through from SANAE to Grahamstown.[11] In winter, when the sun hardly rises above the horizon at points near SANAE, and so causes only a small electron density in the ionosphere, the radio waves escape through the weakly ionized F-region into space and only the lower frequencies are received in South Africa. In summer, however, the sun is permanently above the horizon at SANAE, and during the night it is the darkness near the South African end of the link that controls the maximum frequency we can receive. We are keen to find someone to take this project further.

On two occasions we were able to operate a transportable ionosonde, or our own design and manufacture, on the research ship *RSA* during her return voyage from SANAE; it had been specially arranged that she would sail along the great circle from there towards Grahamstown.[12] Comparison of the ionograms made from the ship with those recorded simultaneously with the Barry ionosondes at the ends of the link was of crucial importance in establishing the above interpretation of the region controlling the maximum usable frequencies. At the same time, the availability of vertical incidence ionograms along the great circle path allowed us to test methods of using the oblique ionograms to deduce the electron density distribution in the ionosphere far from either of the end stations.[10] This work appeared to be very promising during J.Rash's preliminary study and now also awaits enthusiastic continuation to make it a reliable method of studying the ionosphere at sites where there is no ionosonde station.

Airglow observations

Since we were especially interested in the regions of the ionosphere that were bombarded by electrons and protons from space, we proposed a project involving the use of airglow photometers to supplement the ionosondes. They high-energy particles penetrate the upper atmosphere they not only ionize the neutral molecules to produce more ions and electrons; they also excite into higher energy states atoms and molecules with which they collide, and some of these excited molecules and atoms emit photons of certain wavelengths when they get rid of this extra energy. Thus oxygen atoms may emit red light of wavelength 630 nm or green light of wavelength 557.7 nm, whereas nitrogen molecules which happen to have been struck by sufficiently energetic particles may be ionized into an excited state of ion N_2^+ and thus may emit ultraviolet photons of wavelength 391.4 nm. These three wavelengths are commonly observed during the night. The 391.4 nm radiation, in particular, is diagnostic for particle precipitation, because of the large amount of energy involved in exciting the N^2 molecule to the ionic state that emits it. Photometers to measure all these emissions were built at Rhodes University, with the assistance of the CSIR workshops, and have been in operation at SANAE every winter since 1978. Work on the interpretation of these observations has, unfortunately, been severely retarded by the discontinu

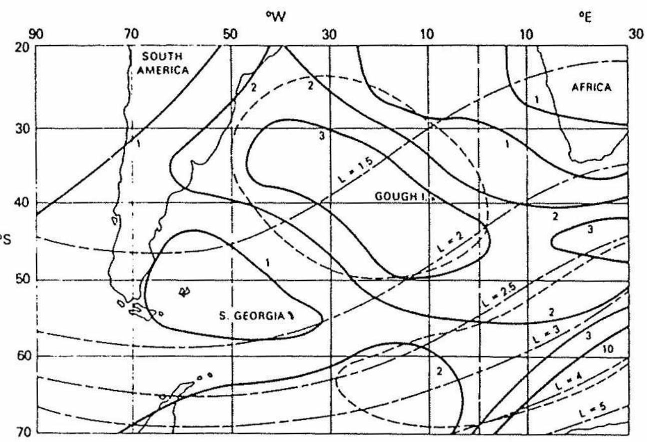

Fig. 5. Map showing contours of energy (in units of m erg cm^{-2} s^{-1}) carried by precipitating electrons with energies in the range 0.2 - 26 keV in conditions of low magnetic activity (from Gledhill and Hoffman[19] published by the American Geophysical Union).

ation of the post of Antarctic Research Officer (Airglow) owing to the present financial stringency.

On most days there are large variations in the geomagnetic field in the polar regions, caused by current in the E-region of the ionosphere, which in turn are due to changes in the state of the solar wind and its interaction with the earth's outermost zone of influence, the magnetosphere. At night it is easy to see that these events are accompanied by auroral displays. Usually there are severe disturbances at all heights in the ionosphere, often accompanied by a complete blackout of ionospheric echoes returned to the ionosonde, due to strong absorption of the radio wave energy in the D-region. Such events are referred to as magnetospheric storms.

During such a storm in July 1979, it happened that there was an isolated 'substorm', in which the perturbations at SANAE were of a fairly simple nature and during which, in addition to the ionosonde and airglow photometers, several other instruments installed by the CSIR Magnetic Observatory and the universities of Natal and Potchefstroom were all operating. As a result, it was possible to compare observations made simultaneously by a number of entirely different techniques, giving an overall view of the history of the event from the time satellites first detected the irregularities in the solar wind, through the effects on the earth's magnetic field and the auroral phenomena and ionospheric manifestations, to the later recovery towards the initial state. This is one of the widest-ranging studies of such events that have been reported in the literature.[13]

Our group has also made contributions to the theory of ionization of the neutral atmospheric constituents by incoming energetic electrons, mainly by using semi-empirical short cuts to allow the more complete theories to be embodied in computer programs that run in a few seconds on computers of moderate power, while still giving results of acceptable accuracy.[14] The final analysis can still be done by the more time-consuming, more thorough programs.

Advanced ionosondes

During the 1970s conventional pulse ionosondes were developed by several groups in the USA, Japan and Australia to give more information about the ionosphere than simply the distribution of ionization in height. This was done by retaining the information about the phase and amplitude of the signals returning from the ionosphere, information that is discarded in the conventional ionosonde. The recent rapid advances in digital data processing methods and computer control of electronic equipment have made it possible to retain this information and use it to obtain the Doppler shift of the returned signal, the amplitude of the signal in easily accessible digital form, the polarization mode and the angle of arrival of the signal if a suitable antenna array is used. These advanced ionosondes are only now coming into use. One is in operation at the British Antarctic Survey's station at Halley in Antarctica and another at Siple, operated by the USA.

In 1975 A.W.V.Poole pointed out that the frequency-modulated technique, on which the operation of the Barry ionosonde depends, could also be used as the basis of an advanced digital system that would have several advantages, and few disadvantages, compared with the pulse ionosondes developed overseas. By using a fast Fourier transform technique and microcomputer control, a very sophisticated new type of advanced ionosonde could be made. The development took longer than expected, but the new digitized FM ionosonde was tested in 1983 and has been operating at SANAE since 1984. Some problems were encountered in the new environment, but these are being solved gradually, and it is quite clear that the new technique promises some unique measurements of ionospheric phenomena. In particular, it is possible to measure the Doppler shift in the frequency of the returned signal at each different frequency on an ionogram, with a precision much better than that attainable with present advanced pulse ionosondes.[15,16]

Atmosphere Explorer-C

Several attempts have been made to operate our portable pulse ionosondes and airglow photometers on aircraft of the South African Air Force, Safair and on ships passing through the regions of the South Atlantic where particle precipitation has been observed from satellites.[17,18] In 1980 the author spent 7 months at Goddard Space Flight Center, in Maryland, as an NAS/NASA Senior Research Associate, making a detailed study of measurements in the south Atlantic of precipitating particle fluxes, made with R.A.Hoffman's detectors on the satellite Atmosphere Explorer-C (AE-C). The main problem that has prevented measurements in the low-energy range, below 30 keV, from being successful is the presence in the South Atlantic Anomaly region of very high-energy particles in the radiation belts, particularly protons. These penetrate the body of the spacecraft and produce such a high rate of spurious counts as to swamp the detectors completely, so that the wanted low-energy signal is almost undetectable against the intense background. On AE-C there were similar spectrometers for positive and negative particles adjacent to each other in the spacecraft. Gledhill and Hoffman established that the positive ion detectors showed the same counting rate for each of the different energy settings in the range for which they were designed, 0.2–26 keV. This could only

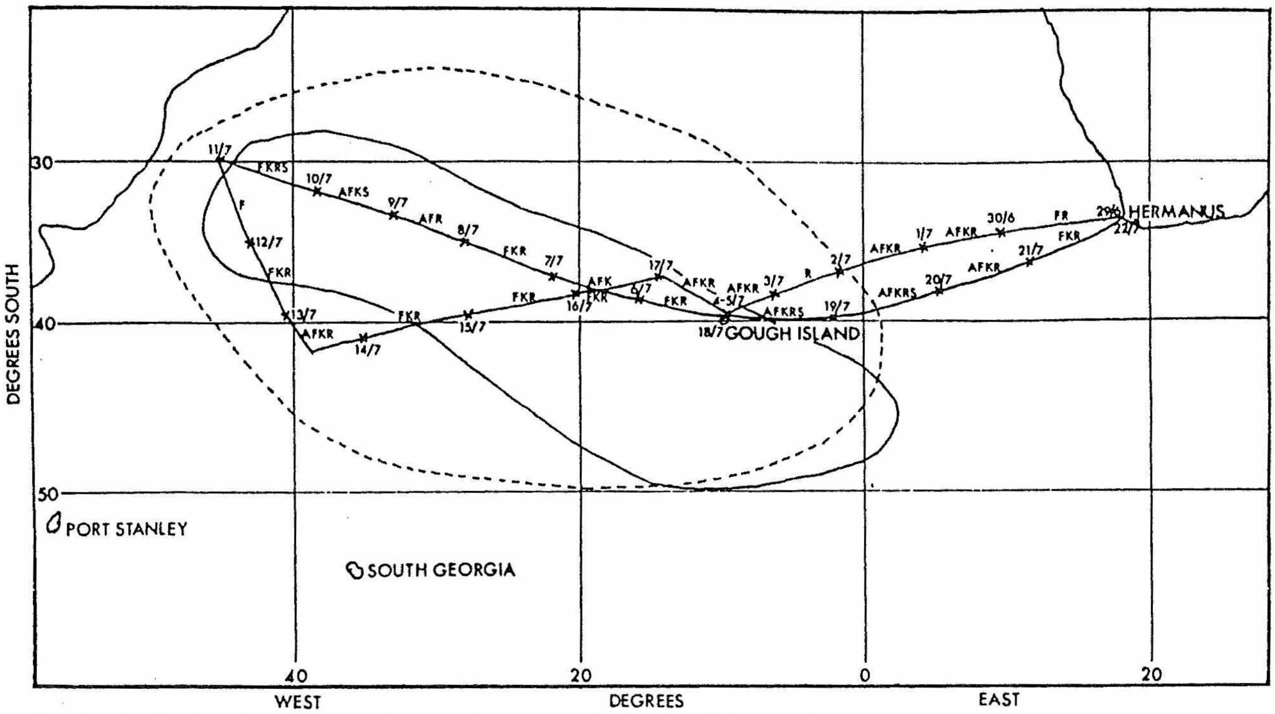

Fig. 6. The South Atlantic Ocean, showing the route of the Project ISAAC cruise. The letters A, F, K, R, and S refer to different types of night-time E-layer ionisation observed, due to particle precipitation. The crosses indicate the ship's position at noon on the date indicated. The dashed curve shows the boundary of the South Atlantic Radiation Anomaly observed by Ginzburg *et al.*[7] The continuous curve shows the 3 m erg cm^{-2} s^{-1} observed by Gledhill and Hoffman.[19] (Reproduced from Dore *et al.*[20] with permission.)

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mean that they were counting the background radiation, and that there were negligible fluxes of protons and other positive ions in the energy range of interest. This was not true of the electron spectrometers, however. They showed a definite variation of counting rate with energy, though there was still a large background count in each channel, typically more than 70% of the total counting rate. By using the ion spectrometer as a background measuring device, it as possible to correct the electron rates for the background and so measure the actual low-energy electron spectrum.

As a result of this, Gledhill and Hoffman were able to publish the first maps showing the distribution of energy deposited in the atmosphere over the South Atlantic by precipitating electrons in the energy region below 26 keV, which is the most important range in producing effects in the E and F regions of the ionosphere.[19] Figure 5 illustrates one of thee maps. It shows clearly the maximum between South Africa and Brazil, somewhat displaced from the maximum flux of the high-energy particles measured by Ginzburg *et al* (Figure 4). Surprisingly, however, there is no trace of a maximum corresponding to that detected by the early Russian and American satellites between South Africa and Antarctica. Another unexpected result was that the energy deposited in the atmosphere by the low-energy electrons *decreased* as geomagnetic activity increased, whereas it was generally expected that it would increase under these conditions.

Project ISAAC

It was therefore proposed to undertake a voyage through the region of maximum precipitation shown on Gledhill and Hoffman's map, operating a modified Barry ionosonde and three airglow photometers on board the SA *Agulhas*. This voyage took place in June-July 1983. Groups in several other countries, especially those bordering on the South Atlantic, Brazil, Argentina and Chile, expressed interest in the project and agreed to make simultaneous observations in their own areas for comparison. Thus emerged project ISAAC (International South Atlantic Anomaly Campaign). The 22 days of observations showed, on detailed examination, many expected and some unexpected results. During many of the nights a type of patchy ionization in the E-region, normally found in the auroral zone where changed particles precipitate sporadically, and therefore called auroral-type sporadic-E ionization, was observed. Ionograms showing other types of E-region trace, known to be produced by charged particle precipitation, were also found (Figure 6); indeed there was only one night among the 22 when observations were made that showed no such particle effects.[20] The ionization of the E-region during the daytime was also found to be considerably more intense than was usual at comparable latitudes elsewhere, and the extra ionization was shown by R.Haggard to vary along the course of the voyage in the way that would be expected if the ionization were due to the distribution of precipitating electrons observed by the Atmosphere Explorer-C satellite. A result still to be explained is that the fluxes of precipitating electrons required to maintain the ionization observed were considerably greater than those measured by Gledhill and Hoffman.

PART II: by A.W.V.Poole

Gough Island

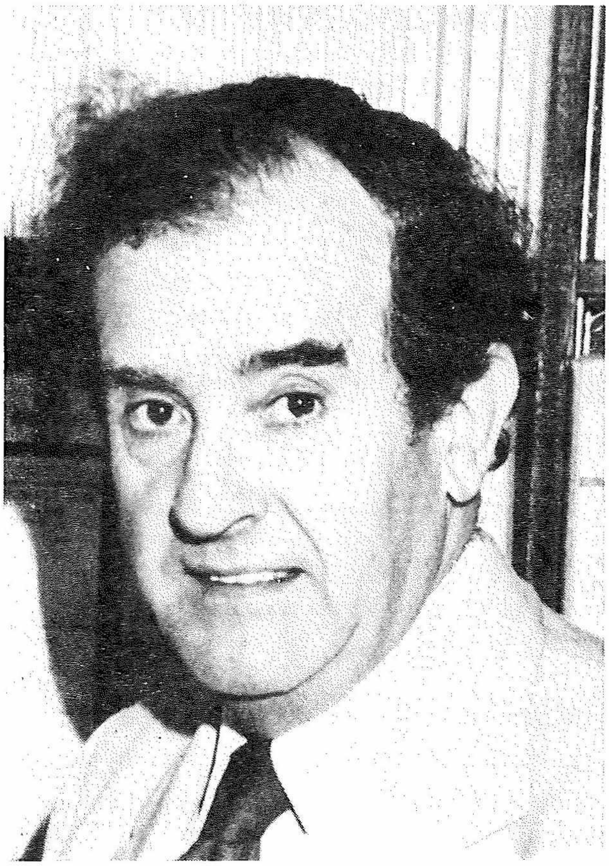
Following the success of Project ISAAC, attention was focussed on Gough Island, which lies in the most intense part of the South Atlantic particle precipitation region. By running an advanced ionosonde at this locality, we would be able to test the theory that the auroral-type sporadic-E ionisation is due to patches of charged particles aligned with the lines of force of the earth's magnetic field. This would offer a reasonable explanation of some of the features of the ionograms recorded on the ISAAC cruise which could readily be confirmed by using the direction-of-arrival capability of the advanced ionosonde.

The idea of setting up a geophysical station at Gough Island was given further impetus by scientific developments within South Africa. Following the world-wide trend, it was decided that Antarctic funding should become more project oriented, and programmes that contained a large synoptic monitoring component were discouraged. The Rhodes group accordingly decided to replace its Antarctic based activities by a more goal oriented research effort in Gough Island, and the SANAE ionosphere programme was terminated at the end of 1989. Central to this research would have been the advanced chirp ionosonde, pursuing the questions described by Jack Gledhill in Part I. Some thought was also given to running VLF receivers to monitor Trimpi events in the South Atlantic Region, and of course the benefits of synoptic ionospheric observations in this remote area of the globe for ionospheric prediction were not lost on the workers in URSI Commission G.

Unfortunately, for non-scientific reasons, this proposal to establish an ionospheric station on Gough Island was not supported, despite strong international interest expressed at the URSI Assembly in Prague in 1990. This decision effectively brought state funding of Antarctic ionospheric research to an end in March 1991, almost exactly 30 years after the historic enquiry by Cyril Hide in late 1960!

Ionospheric pulsations.

A chance juxtaposition of posters by myself and Peter Sutcliffe of the Hermanus Magnetic Observatory at a South African Institute of Physics Conference led to an idea that we run the advanced ionosonde developed by the HOIA group concurrently with pulsation magnetometers. To our great delight we found that geomagnetic pulsations were always accompanied by simultaneous oscillations in the ionosphere.[21] We soon found out that others had observed this, although no-one had seriously attempted an explanation linking the two phenomena. Thus began a theoretical study in which considerable progress has been made in identifying models.[22,23,24,25] The most surprising result was the realisation that the ionospheric perturbations, as evidenced by an oscillating Doppler shift on ionospherically reflected echoes, was not caused so much by up-and-downward movement of the ionosphere, but by compression and rarefaction of the ionospheric plasma under the action of the small pulsation magnetic field.



Jack Gledhill, the author of Part I, died in June 1988. His obituary appeared in the September, 1988, issue of the URSI *Bulletin of Information*.

Conclusion

In June 1988, the Director of the Hermann Ohlthaver Institute, Jack Gledhill, died after a brave fight against cancer. A respected man of international renown, his loss was felt not only by the Institute, but by all his friends and colleagues throughout many lands.

The continued Directorship of the Institute became my responsibility at this time, against a backdrop of reduced financial sponsorships and the consequent loss of valued personnel. Political changes in South Africa have redirected priorities in Government spending, and it seems likely that the Institute will have to operate on a reduced scale for the foreseeable future. Nevertheless, the advanced chirp ionosonde still operates in Grahametown and we continue to produce a monthly bulletin of hourly ionospheric parameters. We have one MSc student and two PhD students currently registered with topics relevant to the Institute. The cessation of Antarctic funding has necessarily meant a shift in research emphasis to more local topics, and these currently include an on-going interest in ionospheric oscillations, as well as an awakening interest in TRIMPI events which we have observed in DECCA navigational transmissions.

The past thirty years of upper atmosphere research described above have resulted in the publication of some 35 papers in international journals and formed the basis of 5 PhD and 13 MSc theses by members of the Rhodes group. The bulk of the finding over the years has come from the Department of Environment Affairs (and formally from the Department of Transport) through the National Projects Scheme of the CSIR. The Herman Ohlthaver Trust provided R250 000 over the five years commencing in 1904. The Institute is currently supported by grants from the MIKOMTEK Section of the CSIR in return for ionospheric data, and the Joint Research Committee of Rhodes University. The financial and logistical support from all these sources, both past and present, is gratefully acknowledged. Without it, none of the work described here would have been possible. The collaboration of many other research workers, both local and overseas, has been an essential part of the overall effort, and I know that Jack Gledhill would have been the first to join me in acknowledging their contribution and thank them for their friendship and help. The Institute will continue to keep the flame of ionospheric research burning brightly at the southern tip of Africa for as long as funds and circumstances allow.

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J. A. Gledhill and A. W. V. Poole

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Interesting and striking photographs for *the Radioscientist* front cover. The subject should be identifiable as radio physics or engineering within the URSI range of Commissions A to K. Until we can afford colour, prints should be glossy black and white and sized to fit on the cover without enlargement/reduction by us. The "portrait" format used so far on our cover is preferred but a striking photograph or graphic (e.g., analogue data) which needs "landscape" mode (short and wide) is also welcome.

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Two books reviewed by James R. Wait

R D Hunsucker, RADIO TECHNIQUES FOR PROBING THE TERRESTRIAL IONOSPHERE, Springer-Verlag, 293 pages, ISBN 0-387-53406-7, New York, Berlin, Heidelberg, 1991.

This is a delightful book. The author has a real feeling for the subject. His purposes are to: examine the basic physical interaction processes of radio waves with the ionosphere, describe the elements of each measurement technique, and assess the limitations and capabilities of the numerous methods available in the literature. Some of the specific topics are: review of the basic electromagnetics, noise considerations, rudimentary plasma physics in classical URSI notation after Appleton and Ratcliffe, specular and scattered reflection from a uniformly graded ionized layer, oblique backscatter, auroral radar, incoherent scatter radar, ionospheric modification including cross modulation theory, special D region problems, satellite topside sounders, whistlers, and ionospheric imaging by radio.

Throughout the book, enough theory is given to nicely complement the excellent descriptions of the actual techniques. Many interesting photographs are provided including remarkable views of the Arecibo HF heater array, the Tromso heater array, Goose Bay HF Groundscatter facilities, Jicamarca Incoherent Scatter Radar array (with an aperture area of 10^4 m^2) and a similar view of the Arecibo ISR facility. The book also contains all sorts of fascinating anecdotes gathered over the years from the author's personal involvement in the subject.

The reference list contains over 400 entries which seem to be all cited in the text. Useful appendices cover such items as symbols, conversion factors, acronyms (5 pages of !), and annotated bibliography to supplement the reference list.

The book should be useful for many years as a bench mark of what has been done in a classical well-trodden field which still seems to be wide open for new discoveries. URSI Commissions G and H people will find the book indispensable but all other radio scientists, like this reviewer, will find the book a valuable reference.

Leland H. Hemming, ARCHITECTURAL ELECTROMAGNETIC SHIELDING HANDBOOK
IEEE Press, 445 Hoes Lane, P O Box 1331, Piscatway, NJ 08855-1331 USA [ISBN 0-87942-287-4] 222 pages, 1992.

This is a rather interesting book. It deals primarily with the practical engineering of shields for closed structures. It brings together a great deal of current knowledge on the subject which has been widely scattered in the published and unpublished reports of R and R organizations. While the principles behind electromagnetic shields have been known for over 50 years, numerous applications have arisen in the past 20 years where the traditional rectangular, double walled, free-standing room will not suffice. Particularly in the past decade, there has been a need to provide an adequately isolated volume which is an integral part of the design and construction of many buildings. The book is intended to assist architects and engineers in the design and specification of shielded enclosures whether encompassing only a small region inside the building or the entire structure.

A useful feature of the book is a complete listing of the jargon used extensively by the practitioners of the art. One entry which caught my attention is : TEMPEST. "A code word (not an acronym) which encompasses the government/industrial program for controlling the emissions from systems processing classified data. Individual equipment may be 'TEMPESTED' or commercial equipment may be placed in shielded enclosures".

An unfortunate feature of the book is that 99% of the references are to reports, unavailable documents, and the trade literature. Also, while the basic theory is covered in an introductory chapter, I found it difficult to see where many of the plotted data could be verified. Certainly the equations (3-2) and (3-3) are not correct. The formula for the surface impedance Z_S of the shield does not have the right dimensions unless a / is inserted before the factor (σ + j w ε). Even in this case it only applies to an infinitely thick shield. Also the formula for the undefined reflection loss R does not make any sense because the quantity in square brackets is complex and again it has the wrong dimensions. The subsequent equations seem suspect but presumably they are not employed in the extensive design data. Never-the-less, I would have some caveats in relying on the quantitative shield attenuation plots scattered throughout the book.

This is the last issue of *the Radioscientist* to be sent free by bulk mail. If you are not a subscriber or an URSI official, take out a subscription now to get all issues of **both** *the Radioscientist* **and** the *Bulletin* sent to you by air up until June, 1993, inclusive, for only US$20. Just send your name, VISA or MasterCard number, card expiry date, or send your cheque, to the Editor by email, fax, letter (see inside cover for addresses).

URSI President visits People's Republic of China

With my first visit to the People's Republic of China, as a project specialist for the Chinese Provincial Universities Development Project to the Department of Radio Engineering of Fuzhou University in South East China (May 11-30, 1991), came also the opportunity to visit Beijing. From June 1-7, I was a guest of the Beijing Broadcasting Institute, the Broadcast Technology Society of the Chinese Institute of Electronics (C.I.E.) and the China Committee for URSI (C.I.E.).

The meeting was arranged for June 3 by Dr Sha Zhong, C.I.E. Secretary General and Zhou Mengqui, C.I.E. Chief for International Activities in the C.I.E. Building. Most of the URSI Committee from universities or research institutes in or near Beijing were present. They usually meet once a year in January, usually in Beijing but also recently in Wuhan. This special meeting was a splendid opportunity to learn first hand the concerns of our colleagues in this vast and important member country. Because all spoke English quite well, the meeting was informal and congenial, as well as informative.

Professor Feng Shizhang of the Chinese Academy of Electrical Technology and President of the URSI Member Committee, began by describing the C.I.E., which might be called the Chinese equivalent of the IEEE, excluding power and control engineering. Founded in 1962, it is a member of the China Association for Science and Technology (CAST). Its membership of 50,000 is enroled in 41 different professional societies and in 29 provincial societies. It sponsors conferences, collaborates with IEEE, URSI and the International Federation for Information Processing and publishes bimonthly Acta Electronica Sinica, which is being renamed the China Journal of Electronics. Selected papers from this journal will be published in a quarterly English language edition.

The URSI Committee in Beijing has as its main task the promotion of academic exchange and research cooperation between Chinese radio scientists and their foreign colleagues. International conferences are the most direct way of doing this and the URSI Committee has recently sponsored in China international conferences on radio propagation, electromagnetic waves, signal processing and radio astronomical methods. They would like to sponsor more.

After I had described some of the current activities and objectives of the URSI Board, members of the committee provided individual comments on their activities and concerns.

Professor Yang Xiaoren of the National Institute of Meteorology in Beijing mentioned that his Commission A has interests in common with all commissions in theory and measurements. This commission spawned the first URSI Commission K in the world as announced in the Review of Radio Science in China 1987-1989 and distributed at the Prague General Assembly. I congratulated the URSI Committee in Beijing for thus anticipating the decision of the URSI Council in September 1990. The Chairman of this Commission K, Professor Zhou Li-Gao of Tsinghua University in Beijing, feels that the present title of Commission K is restrictive; that "Biomedical Electronics" would be preferable to "Bioeffects of Electromagnetic Fields".

Professor Zhou Si Yong of Beijing University of Science and Technology and Commission B Chairman wondered why most of URSI Commission B activities seem to be concerned with theoretical studies rather than experimental studies and antenna design. My own opinion on this is that many of the active Commission B people in Europe and North America happen to be theoreticians. Selection of topics of current interest is decided by the International Chairman and Vice-Chairman of B. It could be changed by the expressed desire of sufficient member committee Commission B Chairmen.

Dr Wu Shengyin of Beijing Observatory (Commission J) expressed concern at the lack of travel support for Chinese radioastronomers to attend international conferences. I had no suggestion to offer at the time but one comes to mind now. Would it be unrealistic to suggest that some of the hard currency surplus from their International Conference on "Radioastronomical Methods of Seeing" should be used to create a fund to support the travel of Chinese radioastronomers? The economic logic for future conferences with this arrangement might appeal to the bureaucrats holding the purse strings.

Professor Wang Yanggyuan of Beijing University has no problem with travel support for our Chinese Commission D Colleagues. Evidently their government anticipates economic advantages from their attendance at international conferences. Professor Wang wondered why URSI Commission D, which is active in optoelectronics, is not also active in microelectronics. I can't remember my answer but supposedly it has to do with the history of Commission D or its predecessor Commission VII on radio electronics which came into existence in 1948 when microwave sources based on wave methods were being perfected. For some time this commission cooperated with other URSI commissions "by bringing to their attention fundamental advances on the physical basis of electronics", rather than by providing a forum for new discoveries. That it has moved strongly into the area of optoelectronics is probably due to the efforts of a few individuals. It could equally do so in microelectronics.

Also present at this meeting was Dr Hu Dazhang, Chairman of Commission F, from the Research Institute of Radio Propagation with which Dr Sha Zhong is also associated. There was also Mrs Zhang Xiaorian, secretary to Dr Sha. They also serve as secretariat for the IEEE Beijing Section.

After our meeting we were joined by my wife for an excellent banquet in the grandeur of the Beijing Hotel. Two days later Mrs Zhang was our guide and companion for a most enjoyable tour of the Summer Palace in Beijing. This was another example of the great kindness and generous hospitality which we received everywhere on our visit to the People's Republic of China.

E. V. Jull

Big in Features — Small in Price GRAPH 2.02 and MINSQ 3.12

In previous issues of the *Computing without Programming* series in *the Radioscientist* we have looked at graphical, numerical and symbolic math packages which cost upwards of $300. In this issue we look at two scientific software packages from *MicroMath software*, a company which aims to produce fully featured scientific software at low prices.

GRAPH is a scientific graph plotting package for PCs which has a price for personal users of only $79. MINSQ is also a scientific plotting program but has more sophisticated curve fitting capabilities and costs $129 for personal users. But how do these software packages compare to their more expensive counterparts ?

Hardware Requirements

You can run either MINSQ or GRAPH on a PC with only two 360kb drives or on a single 720kb 3.5" disk. The program disks are not copy protected, but the first time you run either program, you are asked to enter your name which is subsequently displayed each time either program is started. Version 3.12 of MINSQ and version 2.02 of GRAPH require 640kb of memory to run. The software will use an 80x87 math co-processor chip if you have one installed in your PC. Otherwise all numerical calculations are performed through software. Graphics cards supported include CGA, EGA and Hercules.

GRAPH versus MINSQ

MINSQ is really a superset of the GRAPH program having more sophisticated curve fitting capabilities and most users wouldn't really need to have both programs. Even though GRAPH has fewer curve fitting capabilities than MINSQ, it still offers more curve fitting features than many more expensive graphing packages.

User interface

The user interface for MINSQ and GRAPH is not of the pull-down menu type, and there is no mouse support provided. The menus are based on function keys - to select an item from a menu you press the function key whose name written in front of that item. Menu entries for items not currently available are not displayed.

Data file input format

GRAPH and MINSQ accept ASCII input files and are quite flexible in the numerical format of the data they can read. For example forms like 3.14D8 (meaning "double precision" 3.14×10^8) are accepted.

Input files for MINSQ should have only one x–y pair per line and a blank line signifies the "End-of-File". Multiple datasets can be stored in a single file by using the text 'MOREDATA' to signify the start of a new dataset, and 'ENDATA' to terminate the file.

Input files for GRAPH can also include error bar information. If there is a third numerical entry present on an input line it is interpreted as the size of the error bar to be plotted centred around the data point. For asymmetric error bars the third and fourth entry in a line can be used to specify the lower and upper limits of the error bar for that point.

GRAPH

If you want to do the occasional bit of "data smoothing" and to generate publication quality plots from your data, then the GRAPH program alone will probably be powerful enough for you.

GRAPH has no "three dimensional" surface drawing routines or contour plotting capabilities. But it has most of the usual 2D plotting facilities including extra axes, grid lines, reversed axes, error bars and a bar graph option. Multiple data sets can be overlaid on the same plot and the way the data from each data set is plotted can differ.

Menus in GRAPH enable you to set line styles, symbol styles, symbol sizes, label annotation, units, bar fill style, and optional month labelling for the x axis.

As well as the usual graphics facilities, the GRAPH package can perform:

- Polynomial smoothing and interpolation
- Least squares straight line fitting
- Cubic spline interpolation and smoothing
- Rational fraction interpolation
- Stineman interpolation

Empirical curve fitting is an art as well as a science. The GRAPH manual provides very clear recommendations about empirical curve fitting and on which type of interpolation should be used depending on whether your data can be assumed to be "exact" or whether it contains uncertainty. The GRAPH menus enable you to rapidly switch between different types of interpolation on your data until you find the most suitable.

The GRAPH package also provides facilities for transforming your data. As well as simple translation and scaling of your data using add, subtract, multiply and divide, you also have available: ln, $\log_{10}$, exp, reciprocal, square, square root, abs, integral, derivative and second derivative transformations.

When viewing the plot on your computer screen you can "zoom in" on a selected region of the plot to see it in higher resolution. You can also use the *PlotEdit Menu* to add additional "objects" to the plot including text, lines and arrows. Once you have added objects, you can also move, resize, delete and undelete them.

MINSQ

The MINSQ program combines graphical output, statistical analysis and least squares curve fitting (hence the name MinSq). You can use the built-in editor (which is based on Borland/Wordstar type commands) to create a "model", i.e., a mathematical expression, which you want to fit your data to. The model can be quite complicated possibly including integral and differential operators, and implicit or parametric systems of equations. You can keep a library of your own models on disk and read them in when you want to fit to new data to an existing model.

As well as specifying the model, you must also enter starting values for the minimisation process. At this stage you can also enter any physical constraints on your parameters. For example, a particular physical parameter may only take non-negative values.

The least squares minimisation algorithm used in MINSQ is derived from the Levenberg-Marquardt technique. The basic algorithm has been extended to automatically scale the magnitude of variables and to handle overdetermined systems. In order to find the general region of a minimum a built-in nonlinear simplex algorithm is available.

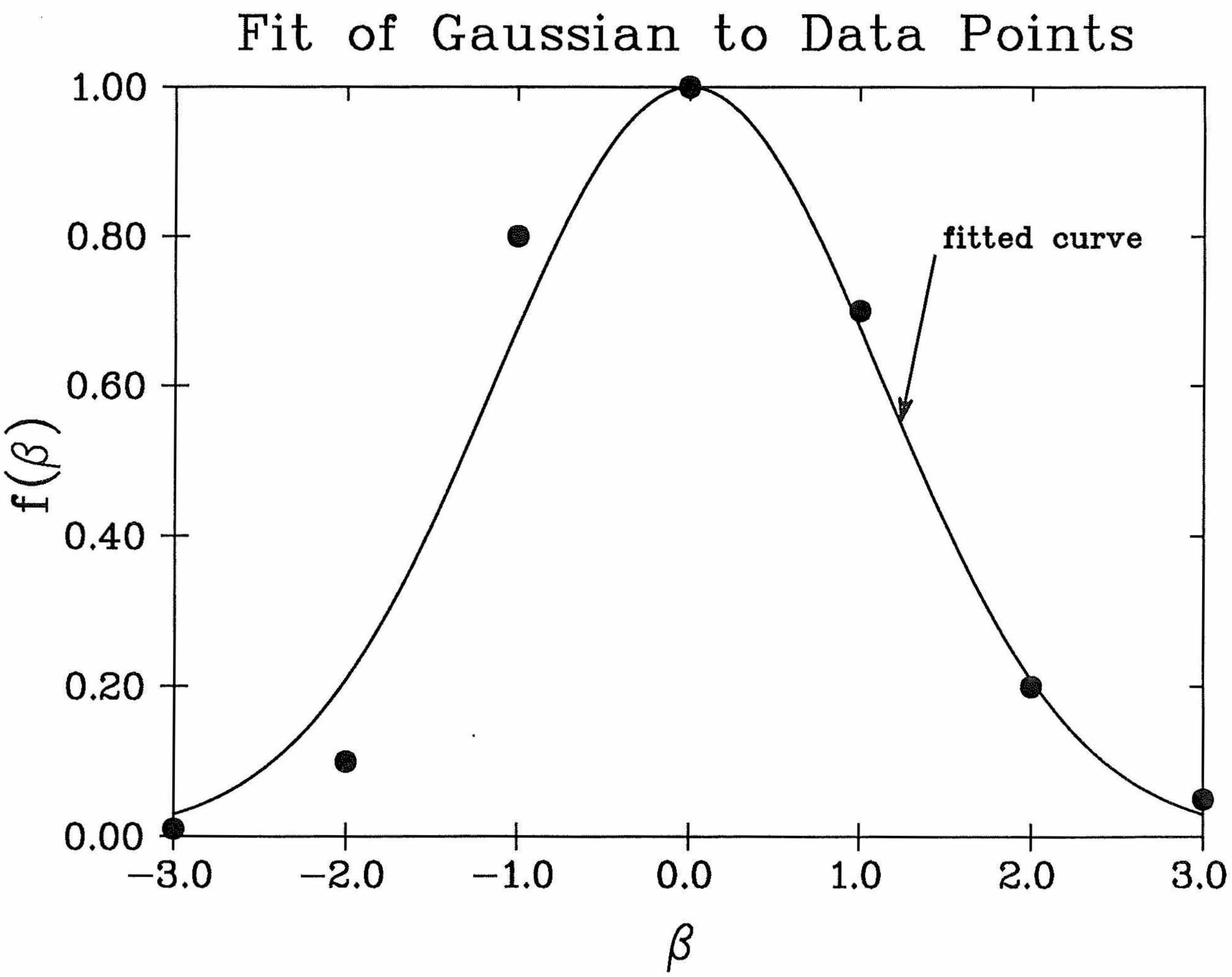
The statistical output from MINSQ includes:

- parameter estimates
- confidence limits
- measures of goodness of fit
- variance-covariance and correlation
- analysis of residuals

Limitations

The largest number of data points that MINSQ can analyze at one time is 200. For many users this number is perfectly adequate, but if you regularly work with large data sets then you may find this computational array size limit too restrictive. MINSQ can, however, read up to 1000 points from a file and cut it down to 200 by throwing away every nth point automatically (not necessarily starting from the beginning of the file). You can also have up to 10 data sets (of 200 points each) in memory at the same time.

GRAPH also has limitations on the size of a single data set, but these are less restrictive (1024 points per data set). You can also have multiple data sets in GRAPH with up to 2048 points in total. You can also instruct GRAPH to discard points when reading in files larger than 1024 points.



Output of MINSQ (or GRAPH which is a superset)

User Manuals

The user manuals for both packages are exceptionally well written with a whole chapter showing example calculations. There was also a whole chapter devoted to a discussion of the algorithms MINSQ uses. A very minor disappointment with both manuals was the lack of an index.

Output

Output from both packages can be produced for HPGL pen plotters and postscript printers. If you are producing output for a postscript printer then both GRAPH and MINSQ enable you to alter the line thickness. This is very important if you want to produce very small or very large plots and still keep the proportion of lines and text to the overall size of the plot. Output line width cannot be altered for pen plotter output.

It is refreshing to see a manual which also provides a section on common problems which arise when trying to interface the software with your printer or pen plotter.

Fonts

The fonts available on GRAPH include sans serif, Roman, Greek, italic, gothic, and two script fonts. After you change the default character set using an option key, the graph must be redrawn in order to see the change on the screen. You can use characters from a second font within a string by using the font escape character "@". This switch is not a toggle, so you need to place it before each character. Sub- and superscripts are easily entered using the "[" and "]" characters in the string. The "[" character means "shift down" and "]" means "shift up". For example x_i is entered as x[i] and x^2 is entered as x]2[.

Demos and support

Demonstration versions of MINSQ and GRAPH are available for $29 each. The demo programs are fully featured and documented but they "expire" within 90 days of purchase. *MicroMath* will also credit the price of the demo program toward the cost of the full program.

MicroMath offer free technical phone support and a dial-up computer bulletin board service for users to exchange information and ideas. Discounts for purchases of multiple programs are also available and are described below.

Upgrade Policy

Major upgrades, including new documentation, cost $99 for MINSQ and $49 for GRAPH. If you purchase a program within three months *prior* to a major upgrade it can be obtained at no charge. Minor upgrades (without documentation) cost $9. Recently *MicroMath* have released version 4.03 of MINSQ and version 3.03 of GRAPH.

Conclusion

Both MINSQ and GRAPH are excellent value for money. Their user interfaces do lack some of the fancy features of more expensive competitors but the existing user interface is easy enough to use. The documentation is very clearly written, honest and easy to follow. Also, if you are already familiar with Borland/Wordstar style editors then entering the models or data will be no problem either.

If you don't routinely work with very large data sets, then GRAPH and MINSQ will do just about everything you want at a fraction of the usual cost.

Product Reviewed

Product:	Minsq version 3.12 Graph version 2.02	
Vendor:	MicroMath Scientific Software P.O. Box 21550 Salt Lake City Utah U.S.A.	
Phone:	801-943-0290 or 1-800-942-6284 (Toll Free US only)	
Fax:	801-943-0299	
Price: (US$)	Minsq (personal version) $129	
	Graph (personal version)	$79
	Minsq (professional version)	$249
	Graph (professional version)	$149

If you order *n* different programs at the same time, you are entitled to a discount of (*n* -1) x $15.

Site licenses for work groups and academic courses are also available.

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