IAGA/URSI
Joint Working Group on
VLF/ELF Remote Sensing of the Ionosphere and Magnetosphere

Editor: A J Smith | Newsletter | No. 5 — July 1993

Dear colleagues,

Every six years the General Assemblies of both IAGA and URSI — the two parent bodies of our working group — occur in the same year. 1993 is such a year. We hope that many of the VERSIM community will be able to attend at least one of these meetings, and take the opportunity to meet and discuss matters of common scientific and technical interest in the VERSIM field. We plan to have meetings of the working group at both Buenos Aires and Kyoto. We will review recent VERSIM activities and consider what role the working group is or should be playing in the future, for example in sponsoring scientific symposia, experimental campaigns, or any another initiatives. If you have any views on this or related matters please bring them to the meeting. If there is any relevant topic which you particularly wish to raise, then it would be helpful if you could let me or my co-chairman Professor Inan know in advance, so that we can put it on the agenda. This issue of the VERSIM newsletter contains information about the general assemblies and other forthcoming meetings, and also news from members of our community in different countries around the world, for example about recent, current and planned experiments in our field. I would like to thank all those who have sent me contributions. I hope you find the newsletter of some interest and will continue to support it.

Forthcoming meetings

IAGA, Buenos Aires, August 1993

The 7th Scientific Assembly of IAGA will be held 8–20 August 1993 in Buenos Aires. A list of the scientific sessions can be found in *IAGA News* No. 30 (December 1991). A meeting of the VERSIM working group is scheduled for the evening of 14 August 1993.

URSI, Kyoto, August 1993

The XXIVth General Assembly of URSI will be held in Kyoto, Japan, 25 August – 2 September 1993. Session H6 is a VERSIM-sponsored session on *Whistlers and Particle Precipitation*. Other sessions which may be of interest to VERSIM scientists are E2 on *The terrestrial electromagnetic environment*, H2 on *Electromagnetic and electrostatic cyclotron waves in magnetospheric and laboratory plasmas: theory, simulations and experiments* and H7 on *Waves in plasmas*. There will also be a lecture by Professor **R A Helliwell** entitled *40 years of whistler research*.

Radio Propagation, Beijing, August 1993

An International Symposium on Radio Propagation (ISRP'93) is to be held in Beijing, 18–21 August 1993. The programme includes a session on ELF/VLF/LF propagation.

EM phenomena and Earthquake Prediction, Tokyo, September 1993

There will be an international workshop on Electromagnetic Phenomena related to Earthquake prediction, held after the URSI General Assembly. That part of the meeting dealing with the possible ELF/VLF precursor signatures of seismic events may be of interest to some members of the VERSIM community. For more details, contact Professor M Hayakawa, University of Electro-Communications, 1-5-1 Chofugaoka, Chofu, Tokyo 182, Japan.

IUGG Boulder, 1995

IAGA will be meeting during the 21st General Assembly of IUGG to be held in Boulder, Colorado. A VERSIM session on *Whistler Mode Waves and Particle Precipitation* has been proposed for the meeting.

Meeting Reports

Indo-Russian Symposium on the nature and variations of the geomagnetic field

From Dr **Birbal Singh** *Dept. of Physics, RBS College, Bichpuri, Agra, India*

This symposium was sponsored jointly by the Indian National Science Academy (New Delhi) and the Russian Academy of Sciences (Moscow) and organised jointly by the Indian Institute of Geomagnetism (Bombay) and IZMIRAN (Moscow). It was held during February 2–6, 1993 at New Delhi. A number of topics dealing with ground, balloon, rocket and satellite-based studies of geomagnetic fields and related phenomena on which investigations are in progress in the two countries were discussed.

A topic related to VERSIM was Active Plasma Experiment (APEX) in space and its effects observed in India through ground-based observations. Three stations in India namely, Agra, Varanasi, and Bhopal were involved to carry out VLF observations of APEX missions. Some triggered events were observed at Agra which appeared to be of great interest to both the Indian and Russian participants.

News from the VERSIM Community

Japan

From Professor **M. Hayakawa** *University of Electro-Communications, Chofu, Tokyo.*

The simultaneous direction-finding measurements of both very low latitude whistlers and their causative sferics have been carried out in order to investigate the detailed propagation mechanism of whistlers from the source to the receiver. The data are obtained from the VLF campaign made in South China.

The dispersion effect of tweek sferics near the cutoff frequencies is utilized to determine the distance of sferics and the ionospheric height by mixing the observed waveform of the sferic with its pseudo-sferic and the subsequent detailed curve-fitting. Also, our field-analysis direction-finding (developed for whistlers) has been applied to tweek sferics to find out the frequency dependence of their wave characteristics (incident angle, wave polarization etc.). This is useful for studying the coupling of lightning discharge energy to whistlers in the ionosphere and to the subionospheric modes.

The effect of subionospheric propagation in whistler spectra has been studied by means of the high-resolution spectral analysis and direction-finding. Almost all very low-latitude whistlers are found to have the additional traces due to Earth-ionosphere waveguide propagation near the cutoff frequencies. This may yield useful information on the coupling of a downgoing whistler to subionospheric modes and the whistler ionospheric transmission mechanism.

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

The satellite (Intercosmos-24) observation of ULF and ELF/VLF radio noises in the ionosphere have yielded that ULF waves tend to be observed mainly before the earthquakes

and over the subsequent earthquake epicenters, but VLF/ELF emissions appear in a wide longitude range. These characteristics are interpreted in terms of the generation of ULF waves in the ground, their penetration into the ionosphere, and interaction with protons, and the associated proton precipitation.

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

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

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

USA

From Dr **U S Inan** *Stanford University*

During the past six months, Stanford University VLF observations have continued and extended as follows. A major new program of observations, motivated by long-path VLF measurement of ambient and modified (i.e. heated by RF injection) D-region electron density and temperature, has been started in Alaska. Three-channel narrowband VLF/LF (10–100 kHz) measurements are presently underway at Fort Yukon, Nome, and Livengood Alaska. Observations at the first two sites have been ongoing since November 1992, whereas the Livengood site has been operational since mid-April 1993. Typically, three channels (24.8, 48.5, 23.4 kHz) are monitored during 0000–1700 UT, and data are recorded with a 10 ms resolution. Summary plots (2-hour per page) are printed at the end of each night and the high resolution data are available on high-density 8-mm Exabyte tape.

A similar Stanford instrument, but with 6-channel capability, has been installed at Gander, Newfoundland, in October 1992 and has been operational ever since. The purpose of this experiment is to measure the effects of the heating of ionospheric electrons by VLF energy originating from ground-based transmitters. Data are typically recorded during 0000-1200 UT with similar characteristics as those in Alaska as mentioned above.

Stanford VLF measurements at Palmer Station, Antarctica ($L = 2.4$) continue as before but with significantly expanded data quality and handling. During the past two months, a new IBM-486 based digital data acquisition system has been installed, increasing data reliability (i.e. continuity of coverage) and ease of handling (8-mm Exabyte tapes). Installation of a new 6-channel Stanford-built VLF phase receiver enables the simultaneous recording of the amplitude and phase of six different VLF signals. Data is typically recorded during 0000–1200 UT with similar characteristics as those in Alaska as mentioned above.

Stanford VLF measurements also continue at 4 sites distributed across the continental United States, including Stanford/California, Huntsville/Alabama, College Park/Maryland and Houston/Texas. The equipment at these sites is in the process of being upgraded, both in terms of the digital data acquisition system (as discussed above) and in terms of the sensors.

South Africa

From Dr **A R W Hughes** *Space Physics Research Institute, University of Natal, Durban.*

An OMSKI receiver, set to receive VLF signals from NAA, NSS, Omega Argentina and Omega Liberia, for studies of the trimpi effect, was installed at Sanae station Antarctica and operation began during January 1993. This is expected to be replaced by an OMNIPAL receiver at the end of this year.

A new low-light-level auroral imaging system, known as WAND (wide angle no distortion), was installed and began operation in March 1993. The main feature of this system is that real time images are recorded in geographic coordinates without further processing.

Construction of the new Antarctic station, to replace the present Sanae, is to begin November 1993 and continue during the summer of 1994–5 with occupation in 1995.

Malcolm Scourfield retired as head of the AMIGO project and from the Space Physics Research Institute but is expected to continue as an Honorary Research Associate after a brief period at the Max Planck Institut für Aeronomie at Lindau. Reiner Friedel, having completed his Ph.D. has joined the same Institute.

France

From Dr **Y Corcuff** *Signals and Communications Laboratory, University of Poitiers.* The Trimpi programme at Kerguelen is continuing until the end of 1993. Similar observations will be started at Poitiers from the end of this year.

New Zealand

From Professor **R L Dowden** *University of Otago, Dunedin*

In November and December 1992 we launched 5 Extended-Life Balloon Borne Observatories (ELBBOs) from Dunedin, New Zealand in an international programme by the University of Washington (Seattle, USA) the University of Otago (Dunedin, New Zealand), and the INPE (San Jose dos Campos, Brazil). The programme involved the design, fabrication and launch of balloon-borne payloads on superpressure balloons into the stratosphere to study atmospheric and space electrodynamics. Each of the three groups provided the instrumentation for the following measurements: vector electric field and associated parameters such as the conductivity (U. Washington); VLF hiss and sferics, and detection and capture of Trimpis from VLF MSK transmitters (U. Otago); and X-rays (INPE). Very similar instruments were used to measure Trimpis at ground stations. The Otago group designed and provided the HF telemetry and ground reception stations, the nonlinear heat diodes (for thermal control of the payloads) and the Omega navigation and ELBBO velocity measurement. (Telemetry and ELBBO tracking was also provided by satellite though ARGOS).

Of these 5 ELBBOs, 4 remained aloft for 3 months or more collecting good data. The longest flight lasted well beyond the 4-month campaign and is possibly still going. The fifth flight had a balloon malfunction, immediately apparent after launch, and only lasted 4.7 days. All longitudes were covered several times over and latitudes covered ranged from low ($< 30^\circ$) to almost 90°. Ground stations for the HF telemetry were at Dunedin, NZ; Perth, Australia; Durban, RSA; Port Stanley, Falkland Is; and Amundsen-Scott South Pole Station. Ground receivers for Trimpi events were at Dunedin (including two other sites nearby), Durban and Faraday, Antarctica.

Phase and amplitude perturbations ("Trimpis") in high power VLF transmissions have not been monitored from such balloons before. These perturbations are produced by short-lived ($\sim$ 30 s) ionisation anomalies. The anomalies are produced by energetic electrons precipitated from the Radiation Belts through amplification of whistlers from lightning. The sign and relative magnitude of the perturbations observed on the balloons, and of ground events sometimes observed simultaneously, and the way these vary with longitude for each of the VLF transmitters monitored (NWC, Western Australia; NAA, Maine, USA; and NPM, Hawaii) will help determine the role of VLF waveguide modal interference, the geographical shape of the ionisation anomalies (elongated E-W?), longitudinal effects and possible effects of high power VLF transmissions on the Radiation Belts, as previously indicated from hiss observations made in the REMAS balloon series of 1983–84.

A more complete account of the ELBBO experiment appeared in *The RadioScientist*, **4**(2), June 1993.

Hungary

From Drs **Gy Tarcsai**, **P. Bognár**, **Cs. Ferencz**, **D. Hamar** and **J. Lichtenberger** *Space Research Group, Department of Geophysics, Eötvös University, Budapest*

The SAS (Signal Analyzer and Sampler) instrument, orbiting onboard the ACTIVE satellite, has been working properly for three years. SAS was constructed at the Microwave Department of the Technical Univer-

sity of Budapest in co-operation with IZMIRAN, Moscow, while its scientific planning, data reduction and analysis has been made at the Department of Geophysics, Eötvös Loránd University, Budapest. In 1991 and 1992 about 280 M-bytes of wave data, measured on 350 satellite passes, have been recorded. Interesting data sets were selected for further analysis. The sophisticated analysis of a number of whistler-doublets, recorded above the ionosphere, indicated that their dynamic (frequency - time - amplitude) spectra exhibited a hyperfine structure, similarly to whistlers recorded on the ground. This behaviour may be explained, for example, in terms of a number of guided modes (waveguide mode splitting) or by the superposition of closely spaced ducting structures (duct splitting).

During simultaneous operation of the low-power VLF sweep generator and the powerful 10 kHz generator on the ACTIVE satellite, narrow-band changing tone emissions were observed by the onboard VLF receivers SAS and NVK ONCH. Their generation mechanisms are studied jointly with the researchers of the Institute of Earth Physics (Moscow) and Institute of Space Research (Moscow).

In cooperation with the British Antarctic Survey (Cambridge) we performed the high-resolution analysis of whistlers recorded digitally in Antarctica, and demonstrated the existence of a hyperfine structure of whistler traces, the source of which is still under discussion. Around 150 whistlers recorded within a time span of several hours exhibited latitude-dependent systematic travel time residuals which are caused probably by the latitude variation of the propagation (ducting) conditions.

In the field of SAS telemetry reception and whistler fine-structure analysis the cooperation between our group and the University of Natal group (Dr. A.R.W. Hughes, R. Friedel and P. Caldeira) has been continued.

We derived directly from Maxwell's equations the full electromagnetic solution for the transformation (dispersion) of an impulse (of arbitrary shape) to a whistler wave, assuming longitudinal propagation in an anisotropic medium. The first numerical calculations using this new theoretical model and several simple impulse shapes resulted in whistler waveforms with properties very similar to those of actually measured nose whistlers.

Using a University of Otago OMSKI receiver, loaned for six months by the British Antarctic Survey, in February 1992, the group was successful in detecting amplitude and phase trimpis on NAA Signals at Érd, near Budapest. In August 1992 Professor R.L. Dowden made a brief visit to Budapest and performed amplitude measurements with the new DSP-based University of Otago receiver ("OmniPal"). Using this receiver the group will participate in an European trimpi-measurement project organised by Professor Dowden and Dr. C.D.D. Adams (University of Otago). The trimpi measurements shall be supplemented by digital whistler recordings in order to study the detailed characteristics of whistlers generating trimpis.

UK

Dr **A J Smith** and Dr **M A Clilverd**, *British Antarctic Survey, Cambridge*

At Halley, Antarctica, we are continuing to make broad-band VLF goniometer recordings on a continuous, synoptic 1-in-5 or synoptic 1-in-15 basis. The analogue magnetic tape recorders will be replaced by DAT (digital audio tape) recorders in 1994. In addition we have continued to operate our VELOX VLF/ELF logger instrument (see VERSIM Newsletter No. 5 for a description), which records VLF activity (power, polarisation, azimuth, minimum/mean ratio etc.) in 8 frequency bands between 500 Hz and 10 kHz, with 1 s time resolution. The first year of data from this experiment, 1992, is now available and will reported upon at Kyoto.

OMSK receivers, designed to study Lightning-induced Electron Precipitation through the study of trimpi events, are currently being operated at Halley and Faraday stations, Antarctica. This is planned to continue on a continuous basis through 1994. Each receiver can record simultaneously the amplitude and phase of two Omega signals and two MSK signals. At Halley we currently receive Omega Argentina, Omega Liberia, NAA (Maine) and NSS (Maryland). At Faraday the selections are Omega Argentina, Omega Hawaii, NAA and NPM (Hawaii).

At Faraday the VLF Doppler experiment

receiving whistler-mode signals from naval transmitters was up-graded in March 1993. The aged PDP 11/23 computers were replaced by MAC IIci. As a consequence of the increase in computing power, four transmitters are now monitored regularly. In addition to the two conjugate transmitters NAA and NSS it is now possible to monitor NLK (Seattle) and FRA (France). Prior to installation, the up-graded equipment was operated on the RRS Bransfield as she journeyed from Uruguay via Halley to Faraday. Whistler-mode signals were received almost nightly south of the Falkland Islands (52° S). Comparative data were recorded at Faraday and Dunedin during the experiment.

Faraday will close as a British manned observatory in March 1996; some experiments (not including VLF observations) may be continued using automated systems.

At Rothera (68° S, 68° W; $L = 2.8$) plans are continuing for the installation of a short-term VLF experiment in collaboration with the USA (Palmer station) and Brazil (King George Island). The experiment will proceed in 1994 and study lightning induced electron precipitation into the ionosphere. The Rothera equipment will consist of a Trimpi detector (OMSK receiver), and broadband (0–10 kHz) VLF recordings made synoptically every 1 minute in 5. The experiment will be installed in March 1994 and operate until October 1994. Supporting recordings will be made from Faraday throughout the austral winter.

Two BAS AGOs (Automatic Geophysical Observatories) have been operating in Antarctica since the 1991/92 season at Halley (for testing) and at site 'A1' (77.5° S, 23.4° W). These each carry a three-axis magnetometer and a riometer. More details were given in *VERSIM Newsletter* No. 3. Some problems have been experienced with the wind generators but these have now been overcome; otherwise the AGO systems have worked well. A third AGO is planned to be deployed in the 1993/94 season, possibly on the Recovery Glacier at around 80.8° S, 20.4° W. It is planned to deploy the first AGO VLF/ELF instrument in the 1994/95 summer season.

Numerical simulation of BAS VLF data from Halley

From Dr **David Nunn** *Department of Electronics, University of Southampton*

British Antarctic Survey at Cambridge have a large data base of VLF data from both Halley and Faraday stations in Antarctica. The data are held on magnetic tape and may be analysed using a sophisticated spectral system called 'AVDAS' (Advanced VLF Data Analysis System). Halley data from L-shells 3–5.5 show many interesting phenomena in the magnetospherically propagated VLF signals. Examples are triggering of multiple emissions by lightning whistlers, triggering of chorus and hiss bands by whistlers, discrete emissions triggered by weak PLHR (power line harmonic radiation) lines, and emissions or chorus triggered by bands of VLF hiss.

Dr A J Smith at BAS and Dr D Nunn at Southampton University have launched a joint project to use a Vlasov simulation code to simulate nonlinear events observed at Halley. The code currently runs on the Cray YMP at Rutherford Laboratory and has already simulated risers triggered by NAA and Siple pulses. The code has also been used in a joint project with Dr D Shklyar to investigate small frequency shifts in NAA MSK transmissions. It is hoped to transfer the code to a Meiko CS2 machine at Southampton University in autumn 1993. This machine has 8 processors and 8 Fujitsu vector processors, and should enable simulation of chorus and hiss bands to be attempted.

Russia/Australia

From Dr **Igor Pimenov** *IZMIRAN, Moscow*

As reported in the last VERSIM newsletter, a new experiment has been deployed at Davis station as part of a Russian-Australian collaboration. In the instrument, developed at IZMIRAN, the two inductive VLF sensors (H and D) have preamplifiers for sending the signals to a VLF receiver. The sensors are oriented so as to minimise unwanted noise. The frequency range of the receiver is 0.8–6.4 kHz. This is divided into three sub-bands, 0.8–1.6 kHz, 1.6–3.2 kHz and 3.2–6.4 kHz separately for each sensor. The outputs in each

sub-band from both sensors are correlated in the receiver and the sub-bands can be monitored and the gain controlled at the receiver panel. The results of the correlations are sent via an analogue to digital converter to a PC and are logged on hard disc. Software on the PC samples the ADC at 2 Hz, takes averages each minute, and displays the average value for each sub-band on the screen. The data are stored in files of one hour duration which can be later examined with software on the PC.

The experiment has been in operation since February 1992 and some data have been sent via satellite and computer links to the IZMIRAN institute near Moscow for preliminary analysis. Recordings on magnetic tape are performed six times a day for three minute intervals. These recordings are direct from the sensors before any processing by the VLF receiver.

The main aims of the experiment are:

1. To study the electromagnetic characteristics of the high-latitude ionosphere by means of registration of VLF waves of natural origin, particularly those generated by storm activity.

2. Detection of VLF waves of magnetospheric origin.

Germany

From Dr **Martin Füllekrug** Institut für Geophysik, University of Göttingen

The Institute of Geophysics, Göttingen, undertakes electromagnetic measurements in the lower ELF range, 0.1–20 Hz. The Schumann resonances that we observe are a global phenomenon and it would be very useful to coordinate our registrations with other working groups in the world to determinate source characteristics and internal properties of the earth-ionosphere cavity.

If anyone is interested, please contact Dr Füllekrug at Institut für Geophysik, University of Göttingen, Herzberger Landstr. 180, D-3400 Göttingen.

Pierre Corcuff

It is with regret that we record the death, on 15 June 1993, of Pierre Corcuff. Based at the University of Poitiers, France, he was an active researcher on whistlers and VLF phenomena. Much of his work was carried out in collaboration with his sister Yvonne Corcuff to whom we express sympathy.

Quicklook plots of VLF tapes

In *VERSIM Newsletter* No. 3, Reiner Friedel of the Natal University group described a "quicklook" system for producing summary spectrogram plots of magnetic tape recorded VLF data, using modern computer graphics technology to replace the traditional photographic film method. He proposed a standard format for such plots. At British Antarctic Survey (Cambridge), in collaboration with High Greave Associates of Sheffield, we have designed and implemented a system capable of producing an output of very similar, though not identical format. The figure shows an example from Halley 1992 data, which features chorus and echoing whistlers. The spectrograms are 0–8 kHz, though other ranges can be selected, and this example is for 1-in-15 synoptic data. With 8 rows of 6 one-minute frames, 12 hours of synoptic data can be contained on a single page. The output is synchronised to the time code recorded on the tape, though an UNSYNC mode in also available for non time code tapes. Although the resolution on a 180 dpi graphics printer (Hewlett Packard PaintJet), $\Delta f = 200$ Hz and $\Delta t = 0.8$ s, is nowhere near that obtainable using a photographic emulsion, the convenience and ease of operation outweighs this disadvantage for survey purposes.

The role of the VERSIM Working Group

The working group serves as a forum for workers studying the behaviour of the magnetosphere and ionosphere by means of ELF and VLF radio waves, both naturally and arti-

ficially generated. Originally the emphasis was on probing of the magnetosphere by whistlers, but recently the scope has become somewhat broader. The group aims to promote research in this field by facilitating the exchange of ideas, information and experience between active research workers and other interested scientists. This is done through regular meetings at IAGA and URSI Assemblies, and via the circulation of a newsletter. The group has also been active in sponsoring scientific symposia at IAGA and URSI Assemblies, in areas relevant to its field of interest, and in coordinating observational campaigns. There are currently 102 scientists from 22 different countries on the VERSIM mailing list. In the interests of economy, it would be helpful to check that we are not mailing to people who are no longer interested. If you wish to remain on the mailing list, I would be grateful if you could take a few moments to complete the reply slip at the end of this newsletter and return it to me. Many thanks!

Please send any information Please send any information of interest to other members of the working group, for publication in the next newsletter, to the editor, **A J Smith**, at the address given below; electronic mail preferred, otherwise mail or fax.

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