Initial results of VLF emissions observed on the ground station at Maitri, Antarctica

Sunil K Singh¹, Sushil Kumar² & A K Gwal¹

¹Space Science Laboratory, Department of Physics & Electronics, Barkatullah University, Bhopal 462 026
²Department of Physics, Faculty of Science, Agra College, Agra 282 002

Received 12 December 2001; revised 17 June 2002; accepted 31 December 2002

The ground based VLF database from Indian Antarctic station Maitri (70°46' S, 11° 44' E, L = 4.6) has been searched for very low frequency (VLF) emissions during January-February of the years 1998 and 1999. The VLF recording system was successfully installed during the XVII Indian Scientific Expedition to Antarctica (ISEA) 1997-98. The spectrograms of analysed data have revealed the common occurrence of various emission events like chorus rising emissions, emission of rising type, falling emission of hook type and multiple emissions. Also the observed emissions (periodic and quasi-periodic) are found to be risers and fallers triggered from the top of hiss band.

1 Introduction

The importance of VLF (0.3-30 kHz) radio waves in the magnetosphere has been long recognized in understanding the plasma physics aspects of wave-generation, amplification and damping through linear and non-linear interactions with particles. The role of waves in the exchange of energy between different regions of geo-space is also important. The popularity of phenomenon of magnetospheric VLF whistler mode waves as a subject of investigation in geospace research stems largely from the fact that they can propagate along the geomagnetic field aligned density irregularities (ducts), penetrate the ionosphere and can be received by simple audio frequency receiver on the ground.

An extensive survey of whistler and VLF phenomena was carried out immediately following the International Geophysical Year (IGY) 1957-58 with more than 50 monitoring stations extending from equator to poles. It soon became clear that Antarctica is an ideal place for VLF research. Further, favourable factors in Antarctica include low levels of both man-made and natural electromagnetic noises. In 1992, a well-calibrated long-term VLF monitoring equipment¹ called VELOX was set-up at Halley and some of the results from this experiment have been reported by Smith and Jenkins². Periodic and quasi-periodic emissions, chorus and various other transient discrete emissions such as VLF risers, fallers and hooks have been reported at Antarctica¹⁶. Smith et al.¹⁴ have reported periodic and quasi-periodic VLF emissions observed at Halley and south pole stations, which are approximately in the same meridian and geomagnetic latitude of 61° and 74°, respectively.

The wave and wave-particle interactions occurring in the magnetosphere generate wide variety of emissions in the VLF range. The VLF emissions are basically mid- and high-latitude phenomena. These emissions over the past decade have become a very important diagnostic tool for proving the plasmasphere and beyond. These emissions although less understood than whistlers, are believed to have their origin in the ionosphere-magnetosphere coupled system and may be due to plasma instabilities or in situ electromagnetic radiations from high-energy particles. The VLF emissions are characterized by their trigger source. The emissions are observed to be triggered from the top of hiss bands by power line harmonic radiation (PLHR), lightning whistlers⁵,⁷, and wave-particle interactions in the magnetosphere. Helliwell⁸ has classified these emissions into hiss, chorus, hook, periodic, quasi-periodic and triggered emissions. The group of VLF emissions is further divided into two sub-groups: (i) continuous emissions in both time and frequency which tend to maintain a steady state such as hiss, resonance bands and noise band near the ion cyclotron frequency, and (ii) discrete emissions often with periodic and quasi-periodic nature.

In this study, we present some events of VLF emissions observed at Indian Antarctic ground station,
Maitri (70° 46' S, 11° 44' E) during January-February 1998 and 1999 as a summer part of the XVII and XVIII Indian Scientific Expeditions to Antarctica.

2 Experimental set-up

A new ground-based station was set up at Maitri, Antarctica, during the XVII expedition in the year 1998 with the same set of equipments as that required for the observations of whistlers. This consists of T-type antenna, transistorized audio frequency amplifiers and digital audio tape (DAT) recorder (model PCM 300) made by Sony Corporation Pvt. Ltd. Hong Kong. The VLF data were recorded with this set-up during summer part of these expeditions. The emissions received, as usual by T-type antenna, were amplified by pre-amplifier kept at the bottom of the pole at which the antenna is installed. The output of the pre-amplifier was further amplified by main amplifier and recorded using the DAT on magnetic tapes. A simplified block diagram of the set-up for VLF experiment is shown in Fig. 1. The data recorded on magnetic tapes were analyzed using advanced very low frequency data analyser system (AVDAS) at Banaras Hindu University, Varanasi and Central Electronics Engineering Research Institute (CEERI), New Delhi.

3 Results and discussion

The VLF emissions for decades have been widely used for investigating the magnetospheric processes of wave generation and propagation, wave-particle interactions, wave-induced particle precipitation and for probing of magnetospheric plasma structures and motions. These phenomena are generally considered to result from non-linear electron-cyclotron resonance or phase trapping in the equatorial region. This occurs predominantly in or near the equatorial plane for two reasons. First, the cyclotron resonance velocity increases as one moves away from the equator and thus number of resonance particles decreases quickly. Second, the ambient field gradient increases away from the equator and eventually suppresses non-linear trapping. From the detailed analysis of the data collected during the expeditions, it is reported here that VLF emissions of chorus riser type frequently occur at Maitri. In Fig. 2, we show the frequency-time spectrogram of chorus riser emission observed on 22 Jan. 1998 at 1045 hrs UT. The mean upper boundary frequency for this riser is 5.5 kHz.

The event in Fig. 2 corresponds to a moderate day, with a daily sum of $K_p$ and $A_p$ indices of 17 and 6, respectively. Morphological features of discrete chorus emissions throughout the magnetosphere have been investigated by several workers on ground and satellite based observations. The studies have revealed that the chorus emissions are observed mainly at $L$-values between plasmapause and magnetopause at all local times. The Indian Antarctic station, Maitri, provides a good situation for the observation of chorus emissions. Figure 3 shows discrete rising emissions on 22 Jan. 1998 at 1050 hrs UT, near a constant frequency of about 2.4 kHz, and have different cut-off frequencies. The rate of rise in frequency ($df/dt$) is also different for these emissions. It can be easily
Fig. 2—Spectrogram of chorus riser emission observed at Maitri, Antarctica on 22 Jan. 1998

Fig. 3—Spectrogram of discrete rising emissions observed at Maitri, Antarctica on 22 Jan. 1998
judged from Fig. 3 that \( \frac{df}{dt} \) is maximum for the first event and minimum for the second case.

The spectra in Fig. 4 shows unusual rising emission recorded on 20 Jan. 1999 in the frequency range 2.5-4.2 kHz. It was a moderate day with three-hourly \( K_p \) values reaching maximum 3 at sixth three-hourly averages, and the sum of \( K_p \) and \( A_p \) were 13 and 8, respectively. The noise below 1.7 kHz is due to instrument, which has been found to occur in our all records. A careful look at spectrogram reveals that the rate of rise in frequency is very high up to about 20 kHz/sec (i.e. \( \frac{df}{dt} = 20 \text{ kHz/sec} \)). As it rises in frequency, the amplitude starts increasing from 2.7 kHz until this riser is cut-off at frequency 4.2 kHz. For some other similar events (not shown here) the starting and cut-off frequency and rate of risers of frequency are found to vary from event to event. In Fig. 5 we present an example of discrete emissions in

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**Fig. 4** — Spectrogram of discrete rising emissions observed at Maitri, Antarctica on 22 Jan. 1998

**Fig. 5** — Spectrogram of typical hook emissions observed at Maitri, Antarctica on 20 Jan. 1999
the frequency range of 4.0-5.5 kHz observed on 20 Jan. 1999 at 1420 hrs UT. An interesting feature of these emissions is that they show hooks near their upper and lower cut-off frequencies. The hook emissions are known to be caused by wave-particle interactions between up-and down-going energetic electrons and whistler mode waves along the field lines near the magnetic equator at higher L shells (L>2) and hence, are generally observed at high latitudes. The detailed study of the VLF emissions observed during these expeditions, their associations with storms and sub-storms, geomagnetic pulsations and their interactions is in progress which may put light on many questions on the nature of these emissions and their relationships to sub-storms and magnetic pulsations.

Acknowledgements

The Department of Ocean Development (DOD), Govt. of India, New Delhi, has funded this project and the authors gratefully acknowledge the help and support of the various officials of this department. One of the authors (SKS) is thankful to CSIR, New Delhi, for financial support. The authors are also thankful and grateful to all the Antarctic Expedition members for their kind logistic support and scientific suggestions.

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