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Observations of a unique VLF emission at Jammu

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Abstract First observations on periodic very low frequency (VLF) emissions at low-latitude ground station Jammu (geomag. lat., 22°26' N; $L \sim 1.17$) are presented To explain the results, it is proposed that the periodic VLF emissions are generated near the equatorial region at $L \sim 1.2$ as a result of interaction between trapped energetic particles and one-hop whistlers under cyclotron resonance mechanism and propagated to our ground station Jammu in nonducted mode of whistler propagation

Keywords Very low frequency emission, low-latitude ground station, whistler propagation.

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Very low frequency emissions (or VLF ionospheric noise) like whistler, is a class of natural radio phenomena [1]. These emissions although less well-understood than the whistlers, are believed to have their origin in the ionospheric/magnetospheric coupled system. If fact, several types of VLF emissions are often observed in close association with whistlers Whistler mode VLF emissions appear generally in two main special groups : (i) Hiss or unstructured emissions characterised by a continuous band limited white noise and (ii) Chorus or structured emissions exhibiting coherent, discrete emissions as short as fraction of a second [1,2]. Some times these emissions reveal periodic or quasi-periodic structures with periods ranging from less than a second upto several minutes. Emissions with regular period below 10 seconds, are known as periodic emissions [1]. However to our knowledge, no reports have been published on the morphological properties of these unique type of VLF emissions (periodic emissions) based on the ground based VLF data at low latitudes. Using an improved system, we have succeeded in recording periodic VLF emission activity for the first time at our low latitude station in India at Jammu (geomag. Lat. 22°26' N) and we present here, categories of sonograms recorded in June 1997.

The successful recording of periodic emissions was first reported by Dinger [3] and subsequently reported by Gallet [4] and Pope and Campbell [5]. The first observation of periodic emission at conjugate stations Byrd-Hudson Bay (Canada) was reported by Lokken *et al* [6]. These emissions were shown to appear alternately at the two stations with a time delay of about 0.8 s. Helliwell [1] reported two distinctive sub-types of periodic emissions. In one type of such periodic emissions called dispersive type, the variational pattern of their period with frequency was found to closely follow the corresponding pattern in the associated echoing whistler. In the second type of periodic emission known as nondispersive, no perceptible change in their period with frequency was detected. In most cases of periodic emissions, the observed period was found to be one third of the two-

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hop whistler transit time and that each third burst appeared to be stronger than the other two [1]. This led to the suggestion that the stronger emissions constituted one distinct set of periodic emissions whose true or 'fundamental' period is three times the 'apparent' period [1]. These emissions are known as multiphase periodic emissions. However among these emissions two-phase emissions are extremely rare [7]. Further, the identification of transit time of two-hop whistler with the observed chorus emissions of characteristic period of 2-3s was reported by Adjepong [8]. Sometimes the frequency of observed periodic emissions was found to change with time. Such emissions are called periodic emissions with frequency drift [1]. The periodic emissions reported earlier were observed in the regions of only closed magnetic field lines and their period was mostly in the 2-6s. The changes in period during observed events, often did not exceed one percent [9]. Recent studies have shown that some types of periodic emissions (hisslers and pulsing hiss) may have periods below 10s, which are not related to the two-hop whistler transit time [10]. To our knowledge, no reports have so far appeared on the recording and morphological properties of periodic VLF emissions from any of the low-latitude ground stations. The present finding is therefore, believed to be the first such event reported from any of the low latitude ground station. Unique VLF spectra of periodic emissions in large numbers, were detected during night time of June 5, 1997 at our field station Jammu during routine recording of VLF waves. A careful analysis of the spectrum of these emissions, reveals unique properties in contrast to those of periodic emissions observed at higher latitudes. The period of observation was a magnetically quiet day with $\Sigma Kp = 6$ (average $Kp \sim 1$) but was preceded by magnetic disturbance on the preceding five days during which the Kp index reached a maximum value of 6.

The recording mechanism of whistlers and VLF emissions at any ground-based earth station is reasonably simple, and less expensive. The basic requirement for the recording of whistlers and VLF emissions is that a voltage is induced in an electric circuit by the low frequency incoming VLF waves. This input voltage is amplified and converted into a form suitable for observation. The recording equipment installed at Jammu consists of an antenna, pre- and main transistorised amplifiers, Filter, Tape recorder and the other accessories. The antenna used at our ground station Jammu, is a simple T-type antenna made up of copper wire 25m in vertical length, about 6 meter long horizontally and 3.3 mm in diameter. This is an omnidirectional antenna with total effective impedance of about 1 MΩ. The antenna is erected at a suitable distance from main building to reduce the power line hum etc. The output of the antenna is fed to the pre-amplifier through a coaxial VLF cable. The purpose of the pre-amplifier is to convert high input impedance to that of low input impedance so that signal from the pre-amplifier can be fed to the main amplifier through the filter unit which is installed in the main building. The specially designed transistorised pre- and main amplifiers are adjusted to a flat response in the frequency range 500 Hz to 15 kHz. The gain of the amplifier is variable from 0–40 dB to avoid overloading of the amplifier at the time of great VLF activity. The pre-amplifier has emitter follower both at the initial and final stage for impedance matching. The main amplifier is also a transistorised type with emitter follower only at the input stage and having a voltage gain variable from 0–60 dB. The output from main amplifier is fed to the magnetic tape recorder (AW666) for the recording purpose. The block diagram of whistler receiver is shown in Figure 1a. The VLF data recorded on magnetic tapes are analysed by an instrument called sonograph. For analysing VLF data, the magnetic tape recorder is played back and the output voltage is fed to the sonograph. The sonograph machine used for this purpose, is shown in the form of block diagram Figure 1b.

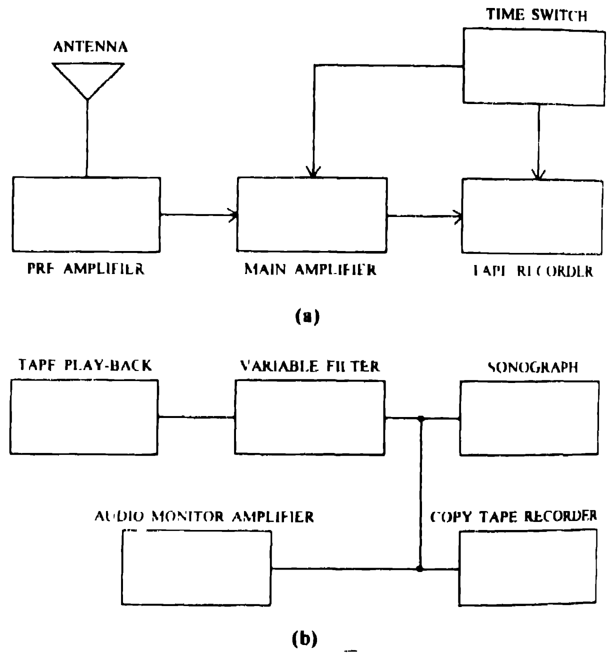

Figure 1. (a) Block diagram of the whistler receiver and (b) Block diagram of the monitor station

This sonograph machine converts the recorded audio signals into the spectrograms (sonograms). The sonograms are the dispersion curves—a plot of frequency (80 Hz–8 kHz) *versus* time (2.4s). The procedure involved is to calibrate time and frequency axis with the help of suitable marker pulses and audio frequency signals respectively.

The quality of VLF signals received at a particular station depends mainly on signal to noise ratio existing at the receiving antenna. Our recording system has been improved upon by introducing a high pass filter unit in between pre- and main amplifiers to reduce the noise to a minimum in the frequency range of 100 Hz to 1 kHz so that even a feeble VLF signal are recorded alongwith strong VLF signals.

On June 5, 1997 at our field station Jammu, the spurt in periodic emission activity started around 2140 IST (Indian Standard Time) and lasted for about one hour ending finally at 2245 IST. During this hour, periodic emissions of different periods were recorded. Out of large number of such events recorded on this day, sixteen sonograms of the recorded emissions are presented in Figure 2. The measured period of emission lies typically in the range 0.1–0.7s, which is much smaller in comparison to that reported from higher latitudes. All the periodic emissions recorded are of nondispersive type having different spectral forms (falling tones, inverted hook *i.e.*, risers followed by falling tone, hook followed by falling tone, and complex combination of rising and falling tones). Figures 2(a, b) show nondispersive periodic emissions of falling tone type in the frequency range 3–3.3 kHz with the periods 0.14–0.2s. Figure 2c shows nondispersive periodic emissions of two bands of activity; upper band of falling tones in the frequency range 3–3.3 kHz, with the periods 0.1–0.3s and lower band of hook followed by falling tones in frequency range 1.7–3 kHz with the periods 0.1–0.3s. Figure 2d shows nondispersive periodic emissions of hook type followed by falling tones in the frequency range 2.7–3.3 kHz with the period 0.5s. Figures 2(e–i) depict nondispersive periodic emissions with two bands of activity; upper band of inverted hooks in the frequency range 3–3.3 kHz and lower band of complex combination of risers and falling tones in the frequency range 2.7–3 kHz with the periods 0.2–0.4s. Further, one-hop multiflash whistlers having dispersion $14s^{1/2}$ are also seen along with these periodic emissions. Figures 2(j–p) shows nondispersive periodic emission with two bands of activity; upper band of falling tones in the frequency range of 3.3–3 kHz with the periods 0.1–0.7s, and lower band of complex combination of risers and falling tone in the frequency range 1.7–2.7 kHz.

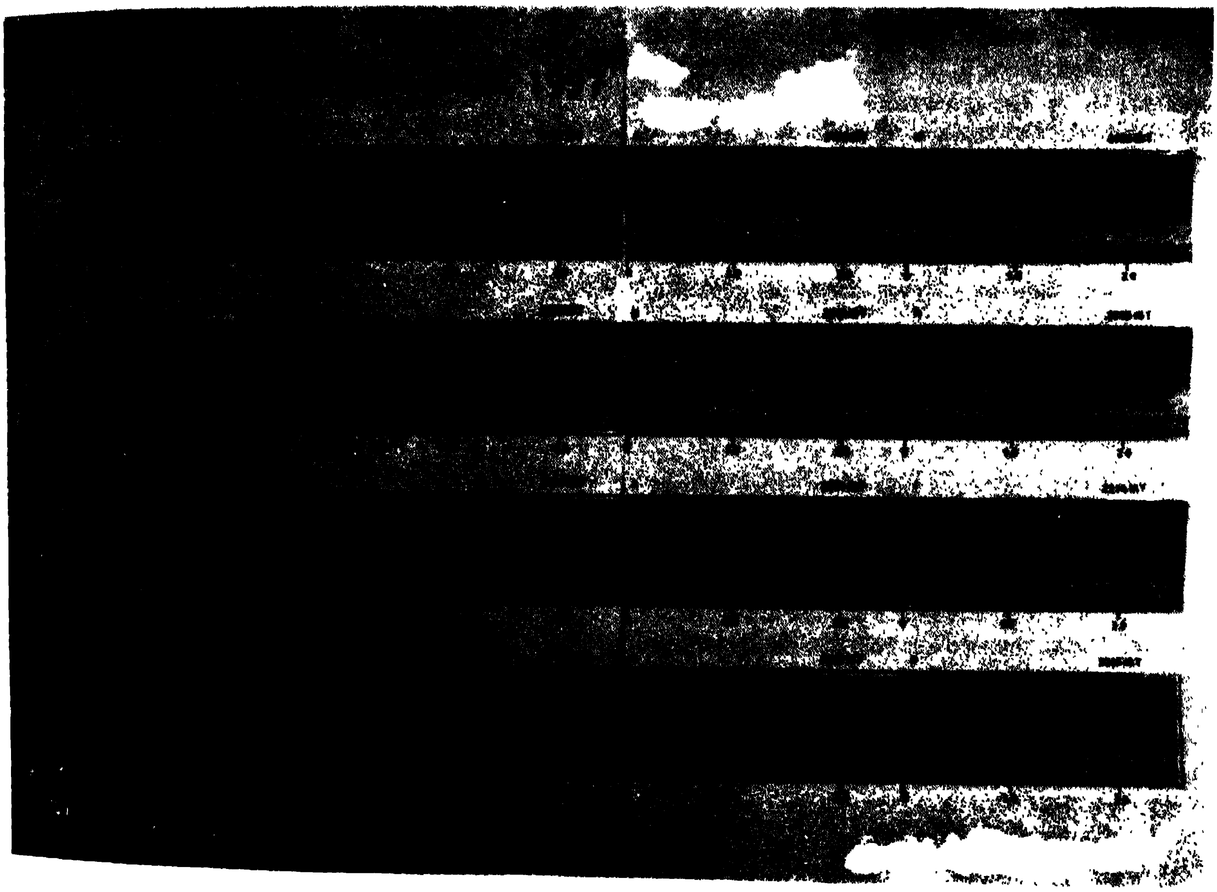

Figure 2. Frequency-time spectrograms of periodic VLF emissions recorded at low-latitude ground station Jammu on June 5, 1997

The simultaneous observations of periodic emissions at conjugate stations, Byrd-Hudson Bay (Canada), was successfully explained with the help of two models suggested by Dowden and Helliwell [11]. In the first model, the emission period was related to the bounce period of the charged particles bouncing between conjugate hemisphere; in the second one, it was related to the two-hop whistler transit time. In order to explain the nondispersive periodic emissions, Helliwell [1,12] has suggested that subsequent bursts of emissions were triggered by the previous ones. Multiphase periodic emissions were understood as a superposition of several periodic emissions. A model was suggested by Dowden [13] who related an 'apparent' period of multiphase to the oscillation period of the 'interaction', as defined by the Helliwell [14]. The unique observation of nondispersive periodic emissions reported here could be well-explained by considering the subsequent burst of emission as being triggered by the previous ones as suggested by Helliwell [1,12]. The very small value of the measured period of the periodic emissions in the range of 0.1–0.7s observed at Jammu, provide an important information about the path latitude of these emissions with the use of direction finding. It clearly depicts that these emissions are generated at low latitude only. It is therefore, proposed that this unique observation of periodic emissions at Jammu are generated near the equatorial region at $L = 1.17$ (Jammu), as a result of interaction between the trapped energetic particles at $L \sim 1.2$ and whistler mode waves under cyclotron resonance mechanism and propagated to our station in whistler mode of propagation.

The periodic VLF emissions recorded at Jammu on June 5, 1997 is a unique observation of VLF emissions in the sense that no such observation of periodic emissions has been reported from any of the low latitude ground station so far and is the first observation of periodic emissions at low latitudes. Further from the spectrum analysis of periodic emissions recorded at Jammu, it is found that these emissions reveal properties of the emission period of the order of 0.1–0.7s much smaller in comparison to that of higher latitudes. Since periodic VLF emissions are sequence of discrete events or clusters of discrete events repeated at regular intervals [1], the morphological properties of the other type of VLF emissions like discrete chorus emissions recorded at low latitudes could be very easily explained with the help of morphological properties of periodic emissions recorded at Jammu. Our detailed spectral analysis of the periodic emissions recorded at Jammu show that these emissions have their origin only in the low latitude ionosphere (inner magnetosphere) and are generated by cyclotron resonance mechanism as a result of interaction between the trapped energetic particles at $L \sim 1.2$ corresponding to our field station Jammu and whistler waves. This is one of the unique observation showing the wave-particle interaction processes taking place in the low latitude ionosphere. Therefore, these results of low latitude ionosphere and the corresponding results already available to those of high latitude magnetosphere will perhaps contribute significantly towards a better understanding of the wave-particle interaction processes taking place in the ionosphere-magnetosphere coupled system. Further, detailed study of these unique periodic VLF emissions observed for the first time is beyond the scope of this paper, and will be reported in a later paper.

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