Pulsing VLF Emissions Observed During Daytime at Low Latitude Station Jammu

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Abstract

The Quasi-periodic pulsing hiss emissions observed during daytime in the frequency range of 50 Hz – 15 kHz at low latitude station Jammu (geomag. Lat. = $22^0\ 26^/$ N; L = 1.17) has been reported. It is noted that pulsing VLF emissions is a rare phenomena at low latitudes. The spectrograms clearly show band limited spectrum regularly pulsing with almost equal period of the order of a fraction of a second in the frequency band 2.6 to 6.8 kHz. Generation and propagation mechanism of these emissions are briefly discussed.

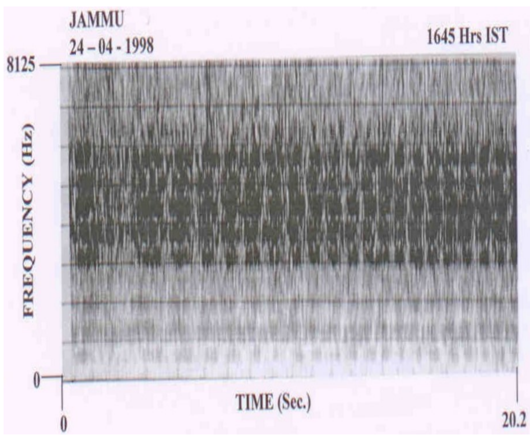
1. Introduction

The name “pulsing hiss” seemed more appropriate as the observed sample spectrograms appeared more to resemble band - limited thermal or fluctuation noise, irregularly pulsing with almost equal period [1]. The wave particle interaction occurring in the magnetosphere generates a variety of emissions in the ELF/VLF range. Amplitude-modulated ELF/VLF emissions observed on the ground were classified by Helliwell [2], who noted various types of periodic emissions, which usually had periods of a few seconds and were often associated with whistler mode waves echoing along geomagnetically field-aligned paths between opposite hemispheres. By contrast, quasi-periodic (QP) emissions consisted of repeated noise bursts of longer (tens of seconds) and more irregular period. Quasiperiodic (QP) emissions were further classified into type-I and type-II [3] on the basis of whether or not they were correlated with geomagnetic pulsations. Hiss-type emissions have been reported which show a degree of periodicity of some what shorter periods (from fractions of a second to several seconds), such as “hisslers” [4, 5] and “pulsing hiss” [1, 6]. These are largely a night phenomenon associated with substorm and pulsating aurora respectively [7].

Although the broad band ELF/VLF hiss emissions are often observed at low latitude ground stations in Japan and India [8-10], but almost there is no evidence of the occurrence of pulsing hiss emissions at low latitudes during daytime. An understanding of the generation mechanism of these pulsing VLF hiss emissions observed during daytime at our low latitude ground station Jammu would be most useful for inferring the properties of high energy trapped electrons. With this aim, we have preformed detailed signal analyses. The purpose of this paper to provide a preliminary description of the most dramatic type of pulsed VLF hiss emissions in the sonogram display recorded at a low latitude ground station Jammu. The results reported here are based on the VLF data collected at our ground-based Indian station Jammu during the years from 1996 to 2006.

2. Experimental Results

The VLF signals are received by a T-type of antenna, amplifiers and tape recorder having band with of 50 Hz - 12 kHz, T-type antenna is 25 meter in vertical length and 6 meter long horizontally and 3.2 mm in diameter. Its impedance is about 1 MΩ. The antenna is rendered aperiodic with the help of a suitable R-C network, to avoid any possible ringing effect. The gain of the pre/main amplifier is varied from 0 to 40 dB to avid over loading of the amplifier at the time of great VLF activity. The observations were taken continuously both during day and nighttimes. The VLF data were stored on the magnetic tapes, which were analyzed using a digital sonograph. Digitization of the analog signal was carried out 16 kHz sampling frequency. The frequency range may be varied from 100 Hz to 40 kHz. Among the VLF data acquired during the span of about ten years of recording, we could only get pulsing ELF/VLF hiss emissions in the years 1998 and 1999 during day hours. Attempts had been made to record such type of emissions at other Indian stations and Singh et al. [6] have only reported observation of pulsing hiss at Varanasi in nighttimes. The observation of pulsing hiss emissions at the ground station Jammu during daytime is rare in the sense that most of the reported observations are mainly from mid/high latitudes [1, 7]. Typical example of pulsing VLF hiss emissions observed during daytime are shown in figures 1 and 2, which are easily recognizable on frequency time spectrograms. Figure 1 shows typical example of pulsing VLF hiss emission observed on April 24, 1998 during daytime in the VLF band in the frequency range of about 3-6 kHz. The day April 24, 1998 correspond to the most disturbed day with sum of K_P indices as 33 ($\Sigma K_P = 33$). The event shown in Fig. 1 were recorded on April 24, 1998 mainly in the late afternoon between 1400 IST (Indian Standard Time) local time to 1700 IST. Pulsing hiss emissions contain equi-spaced pulses of very short duration of about 0.5 sec which are non-dispersive discrete rising tones in the frequency range ~ 3-6 kHz.



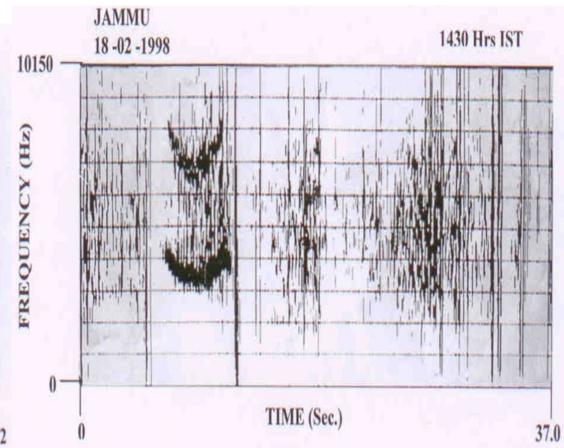


Figure 1. Typical example of pulsing hiss recorded at Jammu during daytime on 24th April 1998 at 1645 Hrs IST.

Figure 2. Typical example of pulsing VLF hiss emission (hyperbolic shape) recorded at Jammu during daytime on 18th Feb.1998 at 1430 Hrs IST.

Fig. 2 shows very interesting events of pulsing VLF hiss emission recorded on February 18, 1998 during daytime in which pulses are of well defined spectral shape (hyperbolic shape) and of longer periods. These event were observed on the most disturbed day February 18, 1998 with sum of K_P indices ($\Sigma K_P = 33_-$). Fig. 2 shows two pulses where the hyperbolic arms run out at different angles and different minimum frequencies at the apical points. The frequencies corresponding to the lower arms of hyperbolic pulses in Fig. 2 (1430 IST) are 4.4 to 5 kHz, with the apical point at a frequency of 3 kHz and occurs for a period of 4.9 sec. Whereas the upper hyperbolic pulse corresponds to frequencies 8.1 kHz with the central depression at 6.7 kHz. The duration of this event is about 4.1 sec.

The pulsing VLF hiss emissions shown in Fig. 1 and 2 have been observed during the period of usual normal VLF hiss activity. Some of spectrogram of VLF hiss in the frequency range 3-6 kHz observed on those days are shown in Fig. 3. From the detailed spectral analysis of the pulsing ELF/VLF hiss emissions it is found that the pulsing VLF hiss emissions are observed in the frequency range of 2.5 to 6.8 kHz. Clearly the pulses in pulsing VLF hiss emission are mainly undispersed band-limited noise bands consisting of multitude of rising tones of burst type and dispersed signal on some occasions consisting of falling and rising tones of hyperbolic shape. Pulsing VLF hiss emissions reported in this paper both occurred in the late afternoon and peaks around 1500 IST local time during quiet and disturbed days, where as the ELF pulsing hiss emission observed on GEOS-2 occurred during nighttime associated with substorms and pulsating aurora [11, 7]. Pulsing VLF hiss emissions with lower cut-off frequency of 2.5 kHz presented in this paper are observed above the waveguide cut-off frequency.

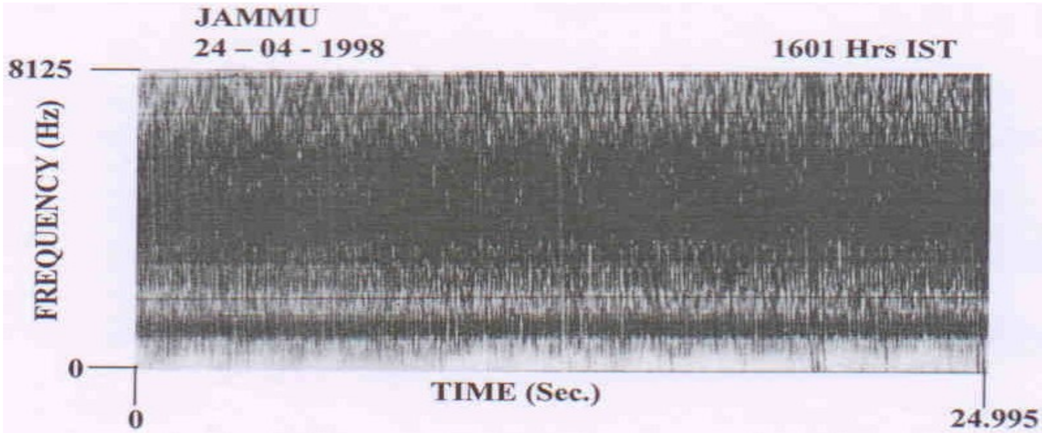


Figure 3. Typical example of VLF hiss recorded during daytime at Jammu on 24 - 4 -1998 at 1601 Hrs IST.

3. Discussions

Detailed analysis of the pulsing ELF/VLF emissions observed at our low latitude ground station Jammu was made to find out the possibility of their occurrence. The possibility that the occurrence of these pulsing hiss emissions was just a coincidence does not seem to be likely because we have observed many events which occurred one after the other during the same day of observation. The origin of pulsing ELF/VLF hiss emissions recorded at low latitude ground station is not clear and hence further experimental studies of these phenomena are needed before we get a clear phenomenological model, which could be a first step towards a physical model. The observed features of pulsing VLF hiss emissions recorded during daytime clearly support the view that pulsing VLF hiss events with a lower cut-off of 2.5 kHz above the waveguide cut-off frequency, generated in the equatorial region of higher L-values reach the lower edge of the ionosphere and excite the Earth-ionosphere waveguide, propagate towards the equator and are received at low latitude ground station Jammu.

The reception of VLF waves on the Earth's surface clearly shows that the waves may have been propagated along the geomagnetic field lines either in ducted mode or in non-ducted pro-longitudinal mode. The source may lie in the equatorial region of low latitudes or in the auroral region. For low latitude source, the path length will be small and hence dispersion would be small. The VLF waves after exciting from the duct, propagate through the ionosphere along the geomagnetic field line towards the Earth's surface. This shows that the attenuation is quite significant for waves propagating through the ionosphere with larger wave normal angles. The VLF hiss generated and amplified to observable amplitudes in the equatorial region of higher L-values may also propagate in non-ducted mode and reach the equatorial zone of lower L-value after magnetospheric reflection. They may also propagate in ducted mode along a lower L-value, which can be received at low latitudes [12]. The wave normal angle of these waves in the generation region may be quite large. VLF hiss reaching low latitudes by this method will not exhibit a lower frequency cut-off caused by Earth-ionosphere wave guide mode propagation. Thus, in absence of direction finding measurements the study of dynamic spectra only can not help us to determine the source of VLF hiss events observed at Jammu. The generation mechanism of pulsing VLF hiss observed during daytime at Jammu could be Cerenkov radiation. Recently, Singh et al. [10] have shown that the Cerenkov radiated power at low latitudes is quite small. To explain the observed ELF/VLF hiss emissions, the radiated wave should be amplified. They have suggested that the radiated wave may be subsequently amplified by the energetic electron present in the medium through the process of Doppler shifted cyclotron resonance mechanism. Pulsing hiss observed on the ground may have propagated along a geomagnetic field line in either the ducted or non-ducted mode. The source of energy could be charged particles spiraling along the field lines. Whistler-mode waves propagating along geomagnetic field lines scatter electrons into the loss cone, which may drive highly localized field-aligned currents leading to the generation of Alfv′en waves that may setup ULF waves along the field lines. Or these would be generated at higher latitudes, and propagate across L shells. Thus, the equilibrium conditions breakdown when considering such fast variations and the interaction between the waves and the electrons becomes a function of time. However, the condition of resonance interaction remains the same, but the physical parameters involved become a function of time. Singh et al. [6] have reported observation of pulsing hiss in the frequency range 3-12 kHz at low latitude station Varanasi. They proposed that pulsing hiss is generated through Doppler-shifted cyclotron resonance interaction near the geomagnetic equator and propagated to Earth in whistler-mode. Singh et al. [6] have also computed the growth rate and shown that the growth rate oscillates and the amplitude of the oscillation decreases as L-value increases. However, the absolute value of growth rate is larger at larger L-values.

4. Conclusions

This paper present daytime observation of pulsing ELF/VLF hiss emissions at a low latitude ground station showing that pulsing hiss emissions are not limited to mid and high latitudes. From the detailed discussions and the characteristics of pulsing hiss emissions observed in two frequency bands (ELF and VLF) during daytime at Jammu show a strong possibility that these are generated in the equatorial region of higher L-values through a process of Doppler shifted cyclotron resonance mechanism. But the origin of pulsing ELF/VLF hiss observed at low latitude ground station Jammu is far less clear and further experimental studies of these phenomena are needed before we get a clear phenomenological model, which could be first step towards a physical model. It seems that model suggested by [13] can be used as a starting point for constructing future self-consistent physical models of most types of quasi-periodic emissions. Further experimental studies are therefore, needed in order that we can choose the best approximations for the mathematical model of quasi-periodic emissions (pulsing ELF/VLF hiss emissions) observed at low latitudes.

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6. References

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