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Characteristics of the observed low latitude very low frequency emission periods and whistler-mode group delays at Jammu

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First observations on the relationship between whistlers and periodic very low frequency (VLF) emissions observed at low latitude ground station Jammu (geomagn. lat., 22° 26′ N; $L = 1.17$) are presented. The results have been discussed in the present paper. 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 the ground station Jammu in nonducted mode of whistler propagation.

The VLF ionospheric noises of natural origin known as 'whistlers' and 'VLF emissions' occur at frequencies between 3000 and 30,000 Hz. Whistlers originate in the lightning discharge and their characteristics are relatively well understood [1-4]. The VLF emissions, on the other hand, appear to originate within the ionosphere and magnetosphere. In fact, several types of VLF emissions are often observed in close association with whistlers. Among the many remarkable types of noises, the VLF emissions are the one that consists of short bursts of noise repeated at regular intervals (order of few seconds) called periodic emissions. These phenomena are readily detectable at high latitudes with a standard whistler recording equipments. However, no report has been published on the observations of this phenomenon from any of the low latitude ground station. The present finding is, therefore, believed to be the first such event reported from any of the low latitutde ground stations.

Using standard whistler recording equipments consisting of a T-type antenna, transistorized pre-, main amplifiers and a magnetic tape recorder, we observed , in large numbers, multiflash one-hop whistlers and periodic VLF emissions during a quiet day on 5 June 1997. This is a unique observation on the relationship between whistlers and periodic emissions recorded at the present low latitude ground station Jammu. The frequency-time spectrograms of these whistler-triggered periodic VLF emissions out of large number of events are shown in Fig. 1 which are photographed on the monitor of the sonograph computer due to non-availability of the printer of the sonograph. A careful analysis of the spectrum of these whistler- triggered periodic emissions reveals unique properties in contrast to those observed at high latitude.

On 5 June 1997 at our field station Jammu, the spurt in periodic emission activity started at around

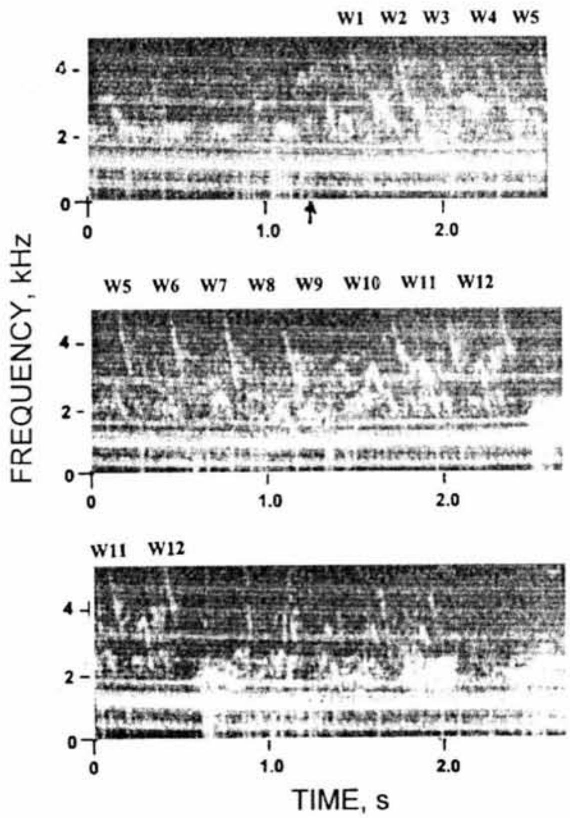

Fig. 1—Frequency-time spectrograms of whistler-triggered VLI emissions recorded at low latitude ground station Jammu on June 1997 at 2215 hrs IST

2140 hrs IST and lasted for about one hour ending finally at 2245 hrs IST. The periodic emissions on this day are of non-dispersive type having different spectral forms (falling tones, inverted hooks, and complex combination of rising and falling tones). The measured period of these emissions triggered by whistlers is found to lie in the range of 0.21-0.26 s which clearly shows that these are generated at only low latitudes. Further, the measured dispersion of multiflash whistlers shown in Fig.1 are very small (of the order of $12s^{1/2}$). The very small value of time period of the order of 0.21-0.26 s of the observed periodic emissions provides us an important information about the path latitude of whistler-triggered periodic emissions without the use of a direction finding. Since the measured dispersion of the whistlers are very small (of the order of $12\ s^{1/2}$), it may be inferred that multiflash one-hop whistlers shown in Fig.1 are low latitude whistlers. Using the empirical relation between the dispersion of whistlers (D) and their path latitude propagation given by Allcock[4] as $D=2.2\ (\phi-12)$ where ϕ is the geomagnetic latitude in degree,the path latitude of multiflash whistlers are found to be $\sim 18^{\circ}$. The estimated value of the generation region of whistler-triggered periodic emissions observed at Jammu is apparently around $L=1.1$. This L value is known to fall in the region of inner radiation belt ($L\sim 1.2$). It is acceptable to presume that the associated periodic VLF emissions have nearly the same wave normal angle as the causative whistler, because both are considered to propagate along the same field line [2].

At the first glance, the whistlers recorded at Jammu appear to be first, third, fifth, etc. hops of multipath whistlers generated from the successive strokes of a lightning discharge. However, the measured dispersion of these whistlers remains constant and hence this possibility is ruled out. Therefore, the whistlers shown in Fig. 1 are one-hop multiflash whistlers caused by different return strokes of a lightning discharge.

From detailed spectrum analysis of the whistler-triggered periodic emissions observed at Jammu, it is found that the time intervals between the consecutive periodic emissions are almost the same as the time delays between any of the two successive hops of multiflash whistlers. The interesting point in Fig.1 is that the time period between any of the periodic VLF emissions and one-hop whistler traces is almost half of the time delay of a one-hop whistler of dispersion ~ $12\ s^{1/2}$ as shown in Table 1. We interpret this unusual relationship between the time intervals of these periodic VLF emissions and one-hop whistlers as follows:

It is assumed that the consecutive periodic VLF emissions of these events were generated as a result of interactions between the trapped energetic particles and the various hops of multiflash whistlers near the equatorial region under cyclotron resonance mechanism and propagated to the present field station in nonducted mode of whistler propagation. Under this assumption, we measure the time intervals between the consecutive periodic emissions at the frequency of 3 kHz and then match them with the delays at 3 kHz between various hops of whistlers. It is found that the observed time intervals of periodic emissions match closely with those of different hops of observed whistler dispersion of ~ $12\ s^{1/2}$ and the time period between any of the two successive periodic emissions and one-hop whistlers of the event are almost half of the time delay of a one-hop whistler of dispersion ~$12\ s^{1/2}$ within about 12% of the measurement error. This shows that time taken by both of the one-hop whistler and the periodic VLF emission is same to reach the receiving ground station Jammu from the equatorial region.

The detailed results presented in the Table 1 clearly depict that the periodic VLF emissions observed at

Table 1 — A comparison of time period between different periodic VLF emissions and time delays between different multiflash whistlers of dispersion ~ $12\ s^{1/2}$

Periodic emissions		Whistlers		Time period between periodic emission and one-hop whistler (at 3 kHz)	
Traces	Time period at 3 kHz	One-hop traces	Time delay at 3 kHz	Traces	Period
1-2	0.23 s	1-2	0.22 s	1-1	0.12 s
2-3	0.23 s	2-3	0.22 s	2-2	0.11 s
3-4	0.26 s	3-4	0.25 s	3-3	0.12 s
4-5	0.24 s	4-5	0.23 s	4-4	0.11 s
5-6	0.26 s	5-6	0.25 s	5-5	0.12 s
6-7	0.26 s	6-7	0.25 s	6-6	0.12 s
7-8	0.26 s	7-8	0.26 s	7-7	0.13 s
8-9	0.26 s	8-9	0.25 s	8-8	0.12 s
9-10	0.24 s	9-10	0.23 s	9-9	0.11 s
10-11	0.24 s	10-11	0.23 s	10-10	0.11 s
1 1-12	0.26 s	11-1 2	0.23 s	11-11	0.11 s

Jammu on 5 June 1997 are generated near the equatorial region at $L \sim 1.2$ as a result of interaction between trapped energetic particles and one-hop whistlers waves under cyclotron resonance mechanism, and propagated to the ground station Jammu in nonducted mode of whistler propagation. This provides a possible explanation to the observed characteristics of whistler-triggered periodic VLF emissions recorded at Jammu (Fig. 1).

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