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ORIGINAL ARTICLE

Detection of 2009 Leonid, Perseid and Geminid Meteor Showers through its effects on Transmitted VLF Signals

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Abstract The detection of 2009 Leonid, Perseid and Geminid meteor showers over Agartala, Tripura, India (Lat: 23.0° N, Long: 91.4° E) will be reported here by using two VLF receivers tuned to subionospheric transmitted VLF signals at the frequency 16.4 kHz from Aldra Island, Norway (Lat: 66.42° N, Long: 13.13° E) and the other at 18.2 kHz from Vijayananarayanam, India (Lat: 8.4° N; Long: 77.7° E). The received signals exhibited their peak values on November 17, 2009 when ZHR (Zenithal Hourly Rate) was highest. Some typical variations which are observed in the records of amplitude during the 2009 Leonid, Perseid and Geminid meteor showers will be presented in this paper.

Keywords Leonid, Perseid and Geminid meteor showers · Zenithal Hourly Rate · VLF transmitted signals

1 Introduction

Meteors during their entry to the Earth's atmosphere, produce electromagnetic waves in the VLF range due to interaction with the medium, which propagate and reach the ground instantaneously (Price and Blum 2000; Trautner et al. 2002; De et al. 2006).

The ionization at the boundary of the lower ionosphere is modified by many geophysical events which include precipitation of energetic particles, solar flares, lightning, earthquake, transient luminous events like sprites and elves. Fixed frequency VLF signals during their propagation through the Earth-ionosphere waveguide space perturbed by any of these natural events will undergo irregular changes in its amplitude and phase. For these reasons, it is used as a tool to study the ionospheric perturbations and their association with the naturally occurring events.

Meteor showers introduce perturbation in ion composition, temperature and other physical parameters within the ionospheric medium at different levels of altitude extending from the lower D-region to the magnetosphere height (Garaj et al. 2000; Nickolaenko et al. 1999; Rodger 2003).

From VLF amplitude and phase observations, solar flare induced ionospheric D-region changes have been investigated (Nickolaenko and Hayakawa 1998; Thomson and Clilverd 2001). Wave propagation below 300 kHz within the Earth-ionosphere waveguide is characterized by various phenomena relating non-homogeneous and anisotropic media.

In this paper, some typical variation of amplitude of 16.4 kHz and 18.2 kHz sub-ionospheric signals due to Leonid, Perseid and Geminid meteor showers will be presented using the recorded data from Agartala, Tripura, India (Lat: 23.0° N, Long: 91.4° E).

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2 Features of the sub-ionospheric signals

2.1 Frequency: 16.4 kHz

Transmitter Call Sign	JXN
Location	Aldra Island, Norway
Latitude	66.42° N
Longitude	13.13° E
Transmitting Antenna	Omni-directional
Power at radiation	Unknown
Operation	Continuous

2.2 Frequency: 18.2 kHz

Transmitter Call Sign	VTX
Location	Vijayananarayanam, India
Latitude	8.4° N
Longitude	77.7° E
Transmitting Antenna	Omni-directional
Power at radiation	Unknown
Operation	Continuous

The transmitted signal frequencies at 16.4 kHz and 18.2 kHz get depleted at the ionized zone during their travel towards the ionospheric layers, due to which effective reception of the reflected signal at the ground will be weak. Higher signal strength is obtained when this type of ionized trail can contribute to the process of reflection of transmitted signals at the VLF receiver along with the reflected waves from the ionosphere.

The day from 15 to 21 November, 2009 had very clear sky and no serious ‘thunder-bolt’ related events were reported at Agartala. So apart from the solar terrestrial influences upon the ionosphere, the period was ideal for observing meteor showers. Moreover, no solar flare events were reported around the period of occurrence by GOES 10 and GOES 12 satellites which continuously monitor solar activity (http://www.swpc.noaa.gov). At the predicted peak activity period, there were no local lightning or flare generated perturbations in the ionosphere that could alter the average signal received at Agartala.

The extra ionization produced by the supersonic meteoroids during their passage through lower ionosphere was the cause of high enhancement of signal level, which is about 3 to 4 dB above the normal value. During the entry of the Leonid, Perseid and Geminid into the Earth’s atmosphere, there would be strong fluctuation of charge distribution in the medium which enhances the rate at which the energy gets randomized. As a result, the relative electron-ion drift velocity may exceed the value for the onset of Kelvin-Helmholtz instability. The compressible ionospheric plasma driven by velocity shears and Earth’s magnetic field at the frontal path of the meteor increases the growth rate of Kelvin-Helmholtz instability thereby generating electromagnetic waves that produce the observed effects in the sub-ionospheric signals.

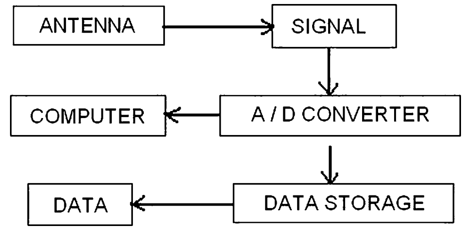

Fig. 1 VLF measurement system

3 Experimental setup

Round the clock measurements of the VLF transmitted signals at frequencies 16.4 kHz and 18.2 kHz are regularly recorded near Agartala, Tripura, India (Lat: 23.0° N, Long: 91.4° E) over the last several years. For the reception of these signals, a straight horizontal copper wire of 8 SWG with 20 m length is used in the form of an inverted L type antenna. The antenna installed at about 10 m above the ground, capable of receiving vertically polarized transmitted signals in the VLF bands from near and far sources of electrical discharges. The recordings of the VLF transmitted signals are made by computerized data acquisition system through a PCI 1050, 16 channel 12 bit DAS card. These are then processed and being stored in a computer. The r.m.s. values of the filtered data are analyzed regularly using Origin 5.0 software. Block diagram of VLF measurement system is given in Fig. 1.

4 Observational results

The occurrence of Leonid meteor shower was detected on November 17, 2009. But there were no remarkable signal strength variations received at Agartala, Tripura, India on November 16, 2009 (Fig. 2). Similar nature of variations was observed upon the signals on November 18, 2009 as shown in Fig. 3. Significant signatures of the meteor showers had been detected on November 17, 2009 in the records of the transmitted signals (Fig. 4).

The Leonids emanate from the trail of parent Comet, 55P/Tempel-Tuttle and the shower activity is significantly variable from year to year. Trail laid down by the comet

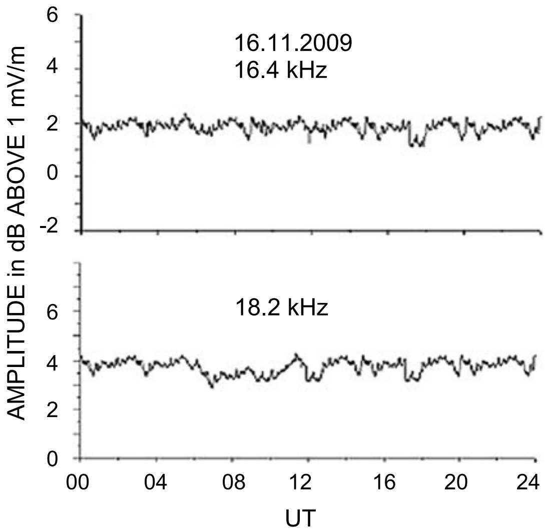

Fig. 2 Variations of strength of VLF transmitted signals in dB above 1 mV/m at frequency 16.4 kHz (*upper panel*) and 18.2 kHz (*lower panel*) recorded at Agartala, Tripura, India on November 16, 2009

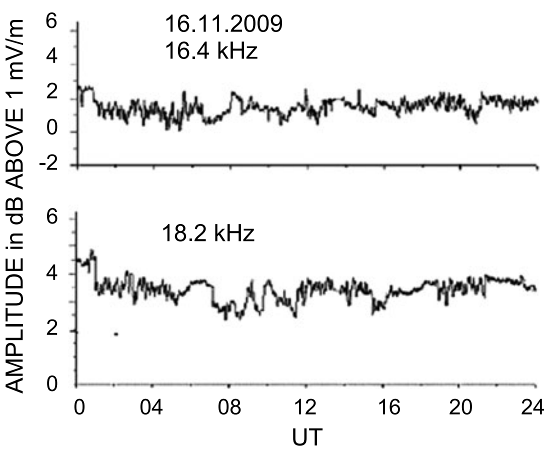

Fig. 3 VLF transmitted signal strength variations in dB above 1 mV/m at frequency 16.4 kHz (*upper panel*) and 18.2 kHz (*lower panel*) recorded at Agartala, Tripura, India on November 18, 2009

in 1466 and 1533 are expected to be the great contributors to the showers. Based on the reports of International Meteor Organization (IMO), Lyytinen and Nissinen (2009) estimated the combined effects of these two trails, i.e., 1466 and 1533, which enhanced the ZHR level to 113 from its lower level on November 17, 2009 at 20:20 hrs UT. Another secondary peak of ZHR level was found on the same date at 23:20 hrs UT with ZHR = 71, otherwise it showed normal value.

In both the cases (Fig. 4), the signal level increased almost by 3 to 4 dB with respect to the normal value. This enhancement is due to the cause of extra ionization produced by the meteoroids during their entry and passage through the lower ionosphere. Some interesting features are observed. The peak activity was noticed earlier than the predicted

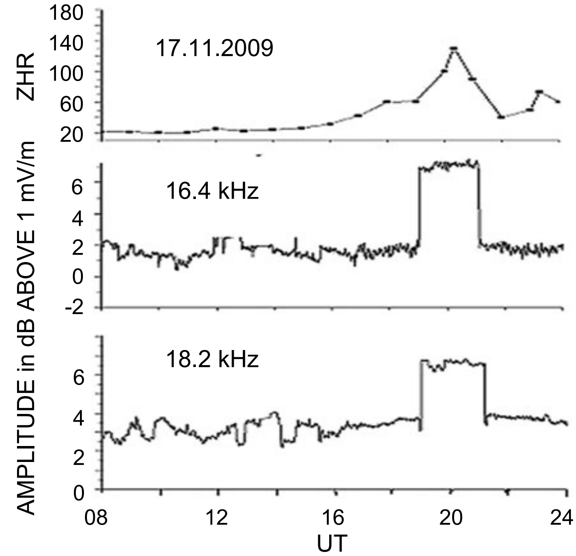

Fig. 4 Signal strength variations of VLF transmitted signals in dB above 1 mV/m at frequency 16.4 kHz (*middle panel*) and 18.2 kHz (*bottom panel*) recorded at Agartala, Tripura, India on November 17, 2009. *Top panel* shows the ZHR variation for the same day due to Leonid shower

times at the highest ZHR. From the ZHR plot, it is found that the two close consecutive peaks of ZHR level occurred at 20:20 hrs UT and 23:20 hrs UT on November 17, 2009 with ZHR values 113 and 71, respectively. The peak activity on November 17, 2009 was observed at 20:20 hrs UT, but the peak activity started at 18:10 hrs UT for the 16.4 kHz signal, which was 2 h 10 min earlier than the observed time and for the 18.2 kHz signal it was 1 h 19 min earlier than the predicted time. Non-gravitational 'A2 effect' on meteor trails may be the cause of this time-shift which is earlier than the predicted peak activities (De et al. 2006).

The enhancement of signal level was also associated with the appearance of Perseid meteor shower. The 2009 Perseid shower showed two peaks in ZHR. The first ZHR peak was observed at around 08:00 hrs UT, August 12, 2009 when ZHR was around 160. Figure 5 depicts the enhancement of signal levels during the period of Perseid shower. The signal levels increased to high values at around 07:30–07:45 hrs UT when ZHR was around 120–125. The signal levels returned to their ambient values when ZHR decreased to around 50. The second ZHR peak at a value of 165 continued for the time interval between 14:30 hrs UT and 19:00 hrs UT on August 12, 2009. The signal level enhanced to high level at around 14:30 hrs UT, when ZHR was 160. The signal levels decreased to their ambient level when ZHR decreased to about 110. The third ZHR maximum occurred at 06:00 hrs UT, when the value of ZHR was about 200. The signal level enhanced to high value when ZHR was of the order of 100.

The enhancement of signal amplitude was also correlated to the increase in ZHR of Geminid meteor shower during

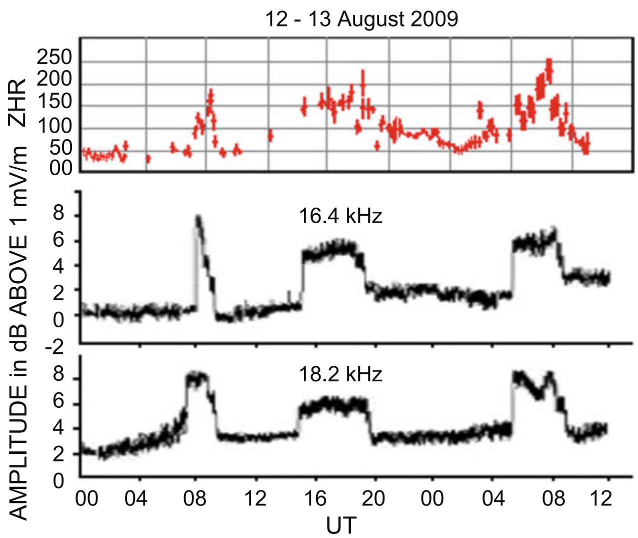

Fig. 5 Signal strength variations of VLF transmitted signals in dB above 1 mV/m at frequency 16.4 kHz (*middle panel*) and 18.2 kHz (*bottom panel*) recorded at Agartala, Tripura, India on August 12–13, 2009. *Top panel* shows the ZHR variation for the same days due to Perseid shower

December 13–14, 2009. Figure 6 shows the enhancement of signal levels during the period of Geminid shower. The ZHR value was large from around 16:23 hrs UT (ZHR = 120) to 19:02 hrs UT (ZHR = 96) on December 13, 2009. The levels of the two signals under observations were increased by 2.5 dB commencing at around 16:00 hrs UT. The signal levels returned to their ambient values when ZHR decreased to a value of about 60. Visual observations of the Leonid meteor shower in 2009 compiled from more than hundred observers round the world (www.imo.net/live/leonids2009/#peak) exhibit the shower peak activity with ZHR = 90 at 20:20 hrs UT on November 17, 2009 and the half maximum activity strength for about 8 hours with almost symmetric ascending and descending branches of activities, which are not the case of the signal strength variations presented in Fig. 4. On the other hand, the steep increase of the amplitude followed by a plateau appeared at about 19:00 hrs UT when the Leonid shower ZHR was 60. Also similar steep decrease is observed at yet higher shower activity. This might indicate that the observed variation of the amplitude was modified predominantly by some other effects than the shower activity.

Unlike the case of Leonid shower, the signal enhancement and the return to the ambient level in the case of Perseid and Geminid showers is in good agreement with the variation of ZHR. The enhancement and the decrease of the signals from their normal levels during Perseid and Geminid showers are appreciably gradual rather than steep variations. In this context, we can consider particle velocities and the declination of the shower with respect to Earth's axis shown in Table 1.

Earlier effect of Leonids on signal amplitude has the implication that the effect started with lower value of ZHR.

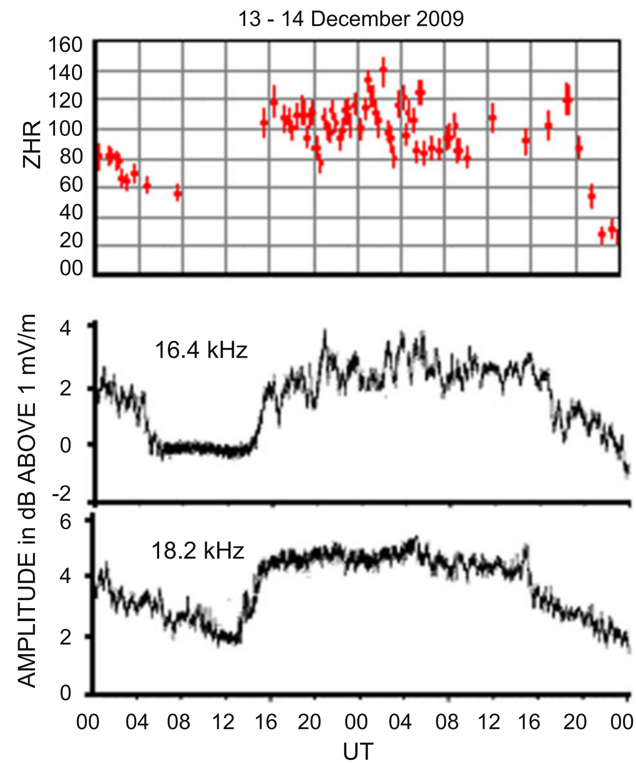

Fig. 6 Signal strength variations of VLF transmitted signals in dB above 1 mV/m at frequency 16.4 kHz (*middle panel*) and 18.2 kHz (*bottom panel*) recorded at Agartala, Tripura, India on December 13–14, 2009. *Top panel* shows the ZHR variation for the same days due to Geminid shower

Table 1 Declination and particle velocity in the cases of three meteor showers

Showers	Declination	Particle velocity (km/s)
Leonids	22°	72
Perseids	58°	60
Geminids	32°	35

This may be due to lower value declination and higher value of particle velocity in the case of Leonid shower. These two reasons can be the causes of appreciable extra-ionization in the D-region of the ionosphere. Due to the extra-ionization, the reflection height of VLF signal is lowered. Under this circumstance, discontinuity appears between the region of extra-ionization and its surroundings. The discontinuity can transfer energy from first mode to second mode of propagation in the waveguide between the Earth and lower ionosphere. A situation may arise where the first and the second modes are in the same phase to interfere constructively. This may be the cause of steep enhancement in the signal amplitude during Leonid shower. On the other hand, if the two modes are in opposite phase, destructive interference between them can lower the signal level to a very low value. In this case, the level will be low even if ZHR is high.

5 Conclusion

The results that are presented here confirm the emission of 16.4 kHz and 18.2 kHz VLF signals from the meteors during their entry into the Earth's atmosphere. The detection of meteor shower by electromagnetic signals is very effective, since the presence of shower can also be detected during daytime unless there is severe thunderstorm activity.

Continuous recordings of VLF subionospheric signals were performed. The analyses of the data show the effects of distinct electromagnetic pulses produced by the meteor showers. The data is always connected by the time series of lightning pulses of very short duration (less than one millisec) having larger amplitude whereas meteor pulses are of longer duration (upto 12 millisec) with smaller amplitude. These two types of pulses belong to different spectra. At the onset of showers, the two time series represent the combined effects of some occasional high amplitude spikes from lightning origin mixed with the increasing number of meteoroids, due to which there will be enhancement of the transmitted signal amplitudes. The transmitted signals exhibited their plateau at the highest value of ZHR.

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References

De, S.S., De, B.K., Guha, A., Mondal, P.K.: Indian J. Radio Space Phys. **35**, 396 (2006)

Garaj, S., Vinkovic, D., Zgrablic, G., Kovacic, D., Gradecak, S., Biliskov, N., Grbac, N., Andreic, Z.: Fizika A **8**, 91 (2000)

Lyytinen, E., Nissinen, M.: In: International Meteor Organization. http://www.imo.net (2009)

Nickolaenko, A.P., Hayakawa, M.: Geophys. Res. Lett. **25**, 3101 (1998)

Nickolaenko, A.P., Hayakawa, M., Kudintseva, I.G., Myand, S.V., Rabinowicz, L.M.: Geophys. Res. Lett. **26**, 999 (1999)

Price, C., Blum, M.: Earth Moon Planets **82**, 545 (2000)

Rodger, C.J.: J. Atmos. Sol. Terr. Phys. **65**, 591 (2003)

Thomson, N.R., Clilverd, M.A.: J. Atmos. Sol. Terr. Phys. **63**, 1729 (2001)

Trautner, R., Koschny, D., Witasse, O., Zender, J., Knofel, A.: Proceedings of Asteroids, Comets, Meteors (ACM 2002), 29 July–2 August 2002, Technical University Berlin (2002)