Phase and Amplitude Perturbations Observed on Subionospheric VLF Signal recorded at Varanasi (L = 1.07) Using SoftPAL Receiver

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Abstract

We report here preliminary observations of phase and amplitude perturbations in VLF signal propagating in the Earth-ionosphere waveguide, monitored at low latitude station Varanasi using SoftPAL Receiver. Phase and amplitude perturbations (trimpis) on VLF signals consists of a sudden change in phase and amplitude of the transmitter signal followed by a slow recovery to the initial levels as the ionization decays. The current understanding of lightening discharge associated processes that leads to the changes in the characteristic of the waveguide and thus variation in the received amplitude and/or phase of the VLF transmission signals have been reported.

1. Introduction

Lightening induced electron precipitation (LEP) events or Trimpi are transient perturbations in the amplitude [1] and/or phase [2] of very low frequency (VLF) or low frequency (LF) radio signal propagating in the Earth-ionosphere waveguide. It is accepted that lightening discharge produce electromagnetic signal from Hz to MHz range. Electromagnetic signal in the VLF (3-30 kHz) range travel as a whistler along field-aligned magnetospheric path where it interact with oncoming energetic electrons (> 40 keV) and scatter them into loss cone which causes the precipitation in the ionosphere, either directly or by backscattering in one hemisphere [1] producing ionization [3]. These precipitating electrons modify the Earth-ionosphere waveguide causing localized ionization enhancement in the vicinity of the VLF reflection height and thus perturb the phase and amplitude of signal from VLF transmitters.

Trimpi events are characterized by a sudden change (over ~1sec) in the phase and amplitude of the transmitter signal followed by a slow (~40sec) recovery to the former level. Most of the work of Trimpi events have been done for high or middle latitude [4] for L>2 or near L=2 [5] where resonant electrons are non-relativistic (E_k<L50keV). Topography of the magnetosphere, the resonance condition for interaction and the energetic particle distribution is significantly different for low latitude as compared to mid and high latitude. A number of workers have given evidence for the wave particle precipitation at low latitude [6, 7]. Gyroresonance conditions at low L suggest that electron precipitation through gyroresonance is worse at low latitudes relative to mid and high latitude.

2. Observation & Experimental Details

SoftPAL stands for "Software Phase and Amplitude Logger", and is a software radio receiver for measuring the phase and amplitude of signals from VLF transmitters using Modulating Shift Keying (MSK) or Interrupted Continuous Wave (ICW) modulation with frequencies up to about 45 kHz. SoftPAL can detect and measure the minute phase and amplitude variations on time scales from tens of milliseconds to months. A simple Citizen's band (CB) antenna of about 1.5 m long is used with the pre amplifier which provides the high gain in MSK (20-25 kHz) band while isolating against power line harmonics. The VLF antenna is almost a pure capacitance of about 10 to 20 pF. So any static charge on it is drained off by 10MΩ resistor of preamplifier in less than 1sec. Pulse from lightening only a few hundred meters away, which could be as much as ± 1000V, are clipped to ± 10V.

Four transmitters: NAA, NWC, JJI and VTX are continuously monitored at our stations Varanasi. Here we have analyzed North West Cape (NWC) transmitter for our analysis purpose which is strongest of all. Figure 3a shows the great circle path of NWC station to Varanasi using an azimuthally equidistant projection centered at Varanasi. Great circles are straight lines under this projection. Continuous recording is done not only to look for daytime classic Trimpi events but also to monitor the diurnal variation. We have obtained Trimpi events with amplitude variations of < 1dB and phase variation of < 5°. In practice signal phase is more stable than the amplitude, and it is possible to detect phase Trimpis even when the amplitude is noisy. During the period of observation from January, 2010 to March, 2010, a total of 87 events were found out of which a major proportion (63 events) have amplitude variation < 1dB and phase variation < 5°. Here we obtain two types of events classic Trimpi events with long event-duration and other unknown events.

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3. Result and Discussion

Phase and amplitude of the VLF signals received from the transmitters is plotted. Amplitude/Phase (A/P) plots show the distribution of Trimpi events on a specific path. Trimpi events can consist of any combination of phase and amplitude perturbation. They may be +/-, means positive amplitude and negative phase perturbation. A commonly used notation is simply +/-, +/+, -/+, or -/-, and for events which have no detectable amplitude or phase perturbation are either +/+ or +/0 etc [6]. Figure 1 shows Trimpi events generation mechanism [6]. The figure depicts the case for "mirrored" precipitation, where interacting electrons first mirror in the hemisphere of originating wave before being precipitated in the opposite hemisphere. LEPs are theoretically unlikely at low L but during magnetic field distortion such as that produced by Pc5 pulsation increases the condition for gyroresonance at low L values and hence Trimpi events.

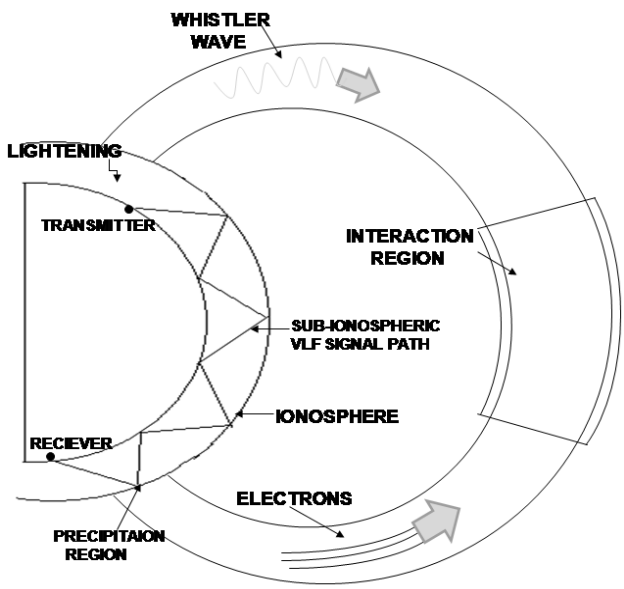

Figure 1. Trimpi event Scenario showing the case of mirrored precipitation. Here interacting electrons first mirror in the hemisphere of the originating wave before being precipitated in the opposite hemisphere.

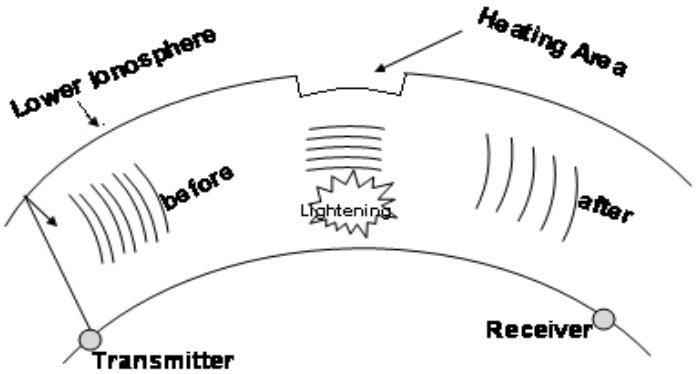

Figure 2. Fast Trimpi event Scenario showing direct ionospheric modification by lightning strikes from below.

To explain Trimpi events one more mechanism is proposed by Inan et al. (1988): "early" Trimpi. In this mechanism direct ionospheric modification by lightening strikes from below is considered to be the cause of Trimpis but not precipitation of particles. This scenario is shown in Figure 2. Here radiated energy from the lightening strikes heats the ionosphere directly above, altering the VLF reflection height for subionospherically propagating VLF signals which are then perturbed. There is also possibility that these perturbations may be from higher latitude coming under the path of propagation of VLF signal from Transmitter to receiver.

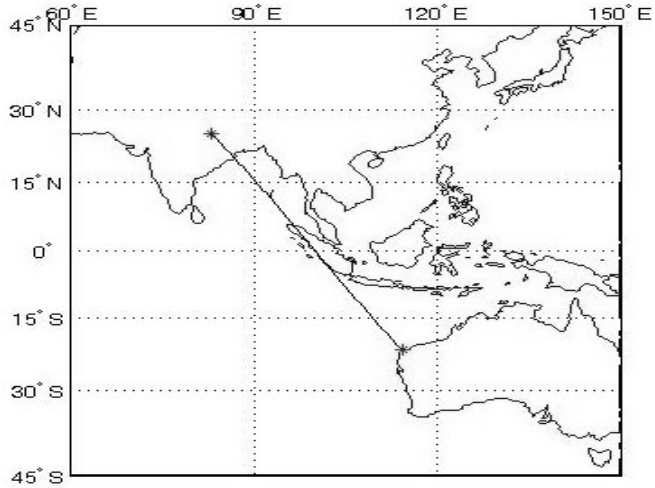

Figure 3. Great circle path of various receivers from Varanasi.

Figure 3 shows the NWC VLF-transmitter and its corresponding Great Circle path which is monitored at Varanasi. Figure 4(a) shows a typical example of a Trimpi event observed at on the NWC-Varanasi signal path with -/+ variation occurred on 06 January, 2010. Here phase of the signal show a slow decay and slow recovery while amplitude show a rapid decay and rapid onset. Figure 4(b) shows the anomalies in the amplitude and phase of transmitted VLF signal observed on January 09, 2010. At 11:47:00 UT there is decrease in amplitude of 3 dB and at 11:48:15 UT, a decrease of 6 dB is observed, which show a valley type structure. Here we observe corresponding increase in phase of about 30 degree and 10 degree respectively.

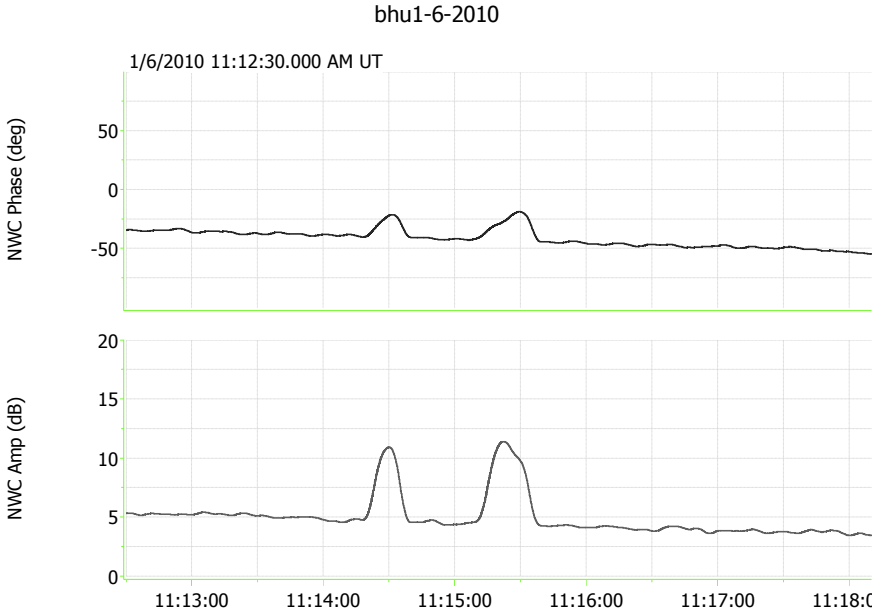

Figure 4 a. Showing Trimpi event observed at Varansi: Smoothed variation

Lightening induced precipitation events such as Trimpis are theoretically unlikely at low latitudes [6]. Since electron energies are relativistic, interaction time is very short and the wave intensities required for adequate scattering is larger than the normally observed in whistler. Gyroresonance at low L values may increase during period of magnetic field distortions such as those produced by Pc5 pulsation [8] and would be a necessary condition for the 'gyres' Trimpi at low latitude [9]. Lightening induced electron precipitation (LEPs) are not enough to account for all Trimpi event at low L value. To account for these Trimpis other factors which enhance gyroresonance at low L must be important. One such mechanism under discussion is the 'early' or 'fast' Trimpi (terminology introduced by Inan et al., 1988.

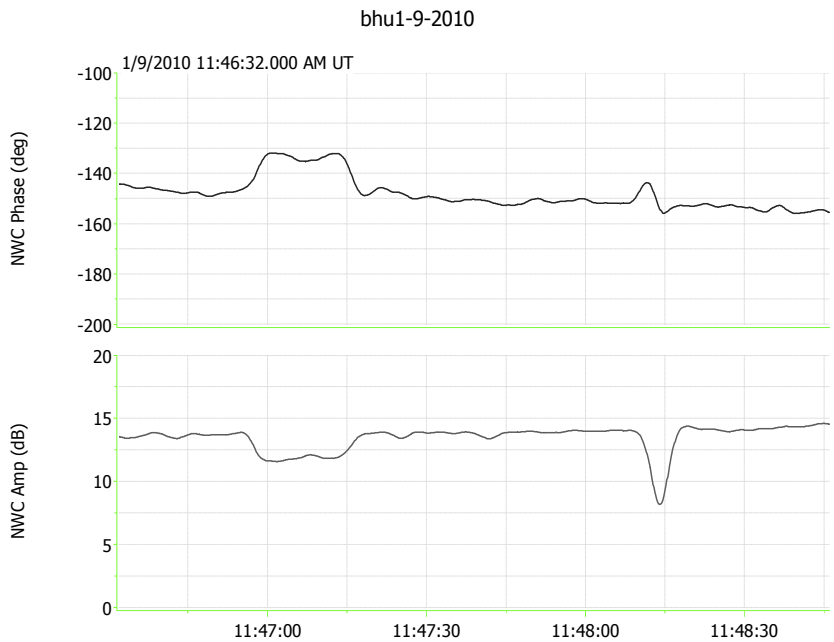

Figure 4c. Showing Trimpi event observed at Varansi: Smoothed variation

Further many workers have shown that wave-particle interaction occurring in the equatorial plane near (L=1.09) can diffuse the pitch angle of the resonant electrons of energy ~ 1MeV so that the particle may be precipitated in the lower ionosphere [10, 11]. This has been confirmed from satellite observations also in which the multiple peaks in the energy spectrum of energetic electrons were detected at the lower edge of the inner radiation belt [12].

4. Conclusion

At Varanasi we observed daytime trimpi like events mostly in afternoon and evening hours which may be caused due to wave – particle interaction occurring in the equatorial plane near L=1.09 or due to the precipitation of electrons in the relativistic energy range. We also observed 'fast' trimpi events which appear to be caused by the direct heating of the ionosphere by lightning strikes. Further extensive study is needed to explain Trimpi events at low latitude.

5. Acknowledgement

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6. References

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