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Study of ELF-VLF Emission and Tweek Atmospherics Observed at "Maitri"

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ABSTRACT

The study of the various geophysical phenomena during quiet and disturbed periods of solar activity gives us a deep insight into the detailed microstructure of microphysical processes taking place in ionosphere, magnetosphere and ionosphere-magnetosphere coupling. Extremely Low Frequency (ELF) and Very Low Frequency (VLF) emissions are one of them and are believed to have origin in the ionosphere-magnetosphere coupled system and may be due to plasma instabilities or in-situ electromagnetic radiation from high-energy particles. The propagation of these emissions in the ionized regions (ionosphere and magnetosphere) provides invaluable information regarding the physical structure and characteristics of these regions. In this paper we have presented the observed hiss with periodic structures at Indian Base Station "MAITRI", Antarctica during the XXIV Indian Antarctic Expedition. The spectral analysis of the Hiss emissions observed during daytime at "MAITRI" station shows that hiss ranges in the frequency range below 2 kHz and maximum intensity around ~1250 Hz.

Keywords: Periodic and Quasi-Periodic emissions, Hiss, Tweek atmospherics, reflection height, Sub-Auroral Region

INTRODUCTION

The unique location of "MAITRI" Indian Research Base Station at Antarctica near auroral latitudes makes it important for monitoring Extremely Low Frequency (ELF) - Very Low Frequency (VLF) wave phenomena. It is well known that the auroral oval is a region of closed magnetic field lines mapping through the plasma sheet. In characterizing the generation of ELF-VLF waves and their subsequent energization of auroral ions, a larger scale energy transfer process may be observed due to the energetic auroral electrons, emit intense emissions. Such a links in the auroral plasma environment would fill an important gap in the understanding of how ionospheric ions are transported into the magnetosphere. The wave and wave particle interactions occurring in the magnetosphere generates wide variety of emissions in the ELF-VLF range. The study of plasma wave–particle interactions and particle acceleration has been an important focus for understanding the dynamics of the Earth's auroral and sub–auroral ionosphere. Out of large number of ELF-VLF wave phenomena, VLF emissions are important process, which plays a vital role in probing the Earth's ionosphere and magnetosphere. VLF emissions are naturally occurring waves which are believed to originate in ionosphere or magnetosphere that propagates in magnetized plasma in whistler mode and are readily detectable at mid and high latitudes. VLF emissions propagate along the magnetic field lines of the Earth get dispersed due to field aligned irregularities. These emissions are localized geographically at the locations that are geomagnetically conjugate to one another (Helliwell, 1965). The popularity of this phenomenon as a subject of investigation in geospace research stems largely from the fact that they can propagate along the geomagnetic field aligned density irregularities, penetrate the ionosphere and can be received by simple audio frequency receiver on the ground. The emissions are observed to be triggered from the top of hiss bands, by power line harmonic radiation (PLHR), lightning whistlers (Helliwell, 1965, Sazhin et al., 1993;Nunn and Smith 1996;Smith and Nunn, 1998) and wave particle interactions in the magnetosphere. The variety of phenomenon encountered within the narrow band of frequencies is both bewildering and fascinating. For example, the VLF waves propagating in the space between the Earth and lower ionosphere (conveniently, the D or E region) are found to suffer very nominal attenuation except in the so-called absorption band (1-3 kHz). Similarly, the propagation of these waves in the ionosphere and the magnetosphere provide us with valuable information regarding the physical structure of these regions. Also, our understanding of the mechanism of the generation of certain types of VLF signals in the ionized regions of the upper atmosphere involves a fascinating interplay of subtle theoretical concepts and sophisticated experimental techniques in the field of plasma physics.

High Latitude Emissions and Data Acquisition

The ELF-VLF emissions are basically mid–and high-latitude phenomena and are believed to have origin in the ionosphere–

magnetosphere coupled system may be due to plasma instabilities or in-situ electromagnetic radiation from high-energy particles and during lightning discharges. It has been since recognized that these waves play an important role in the loss of electrons from the radiation belts (Kennel and Petschek 1966; Gurnett et al., 1990). Observation of these ELF-VLF emissions at ground station indicates that the waves, after generation, may have propagated in the ducted whistler mode or pro-longitudinal mode because ELF-VLF wave propagating in any other mode may not reach the Earth's surface. Various types of ELF-VLF emissions are observed at high latitudes the most frequently observed are chorus and hiss emissions. Auroral Hiss emissions are distinguished from other types of natural radio emissions according to the form of their spectrum, which presents a band-limited thermal noise, producing a hissing sound, and their localization in the vicinity of the auroral oval. These emissions are observed in a wide frequency range, from a few hundred Hz to 50 kHz and even higher (Sazhin and Hayakawa, 1992; Reber and Ellis, 1956; Martin et al.,1960; Jorgensen, 1968; Makita,1979; Benson and Desch,1991; Hayakawa and Sazhin, 1992) and are classified into two types- continuous hiss and impulsive hiss. Continuous hiss does not reveal any large change of the spectrum structure for several minutes and even for hours; impulsive hiss spectra can change considerably, even within seconds (Helliwell, 1965). A sequence of discrete events or clusters of discrete events showing regular spacing is called a set of "periodic emission" (Helliwell, 1965; Sazhin and Hayakawa, 1992) usually their time separation is constant, but it may on occasion change slowly. The periodic emissions are observed at latitude that corresponds to close to magnetic field lines and are rarely observed on satellites (Helliwell, 1965). Periodic emissions are classified as: if the period varies with the frequency, the periodic emissions are called "dispersive". If there is little or no variation with frequency, the periodic emissions are called "non–dispersive", two or more interleaved sets with the same period are called "multiphase periodic emissions". In this type of emission the number of phases equals the number of sets. The periodic emissions are assumed to have propagated in field aligned ducts. A sequence of repeated noise bursts of relatively long period, in which each burst may consists of number of discrete events, periodic emissions, or chorus, or diffuse hiss is called "quasi–periodic emission" (Helliwell, 1965). The period between bursts is usually measured in tens of seconds and is relatively irregular compared with that of the periodic emissions. Quasi – periodic emissions are special phenomena and they have been observed more on satellite than on the ground (Sazhin, S. S. and M. Hayakawa, 1994). Amongst different kinds of emissions, hiss emissions are well-known forms of electromagnetic emissions that arise in the magnetosphere and have constant spectral density in the limited frequency. Chrous is intense plasma wave that penetrates magnetospheric regions between the plasmas pause can be observed on the round over a range of latitudes (Salvati, 2000). Sometimes; complex combinations of these emissions are also reported. Periodic and quasi-periodic emissions, chorus and various other transient discrete emissions such as VLF risers, fallers and hooks have been reported at Antarctica (Sazhin, et al., 1993; Smith and Nunn, 1998; Morrison et al., 1994). It has been Smith et al., (1998) have reported periodic and quasi- periodic VLF emissions observed at Halley and South Pole stations. Periodic VLF emissions are observed only in the regions of closed magnetic field lines (Sazhin, S. S. and M. Hayakawa, 1994). Their period was typically in the range 1 to 7sec., but most frequently in the range 2 to 6 sec. The changes in period during observed events often did not exceed 1% (Helliwell, 1965). Earlier workers (Singh, et al., 2003; Singh, et al., 2003b; Patel, et al., 2003) at “MAITRI” reported various transient discrete emissions such as Riser, Faller and Hooks daytime discrete chorus periodic emissions near 2.5 - 6.8 kHz, hiss in the frequency range 11-13 kHz and 13-14.5 kHz and some riser type emissions in the frequency range 3-5 kHz and magnetospheric lines at about 6.2, 8.0 and 9.2 kHz during daytime.

Quasi-periodic (QP) whistler emissions are wide-band emissions that are observed inside or near the plasmapause (Heliwell, 1965; Hayakawa and Sazhin, 1992; Sazhin and Hayakawa, 1994; Smith et al., 1998). They are characterized by a periodic modulation of the wave intensity with typical periods from several seconds up to a few minutes. Generation of QP emissions is usually accompanied by the precipitation of energetic particles, which are also modulated by the same period. Morrison et al.,(1998) used ELF-VLF and magnetic field observations from South Pole Station, Siple Station, and Halley Station to compare QP and Pc3 magnetic pulsations and showed QP signals occurred in phase (to within the 1-sec sampling rate) at each station, while simultaneously observed Pc3 activity showed no coherence between stations.

To obtain proper understanding of the propagation and generation characteristics of high latitude ELF–VLF emissions, recordings were carried out at Indian Base Station, “MAITRI” (70° 46`S, 11° 44`E, L ~ 4.6) at Antarctica, during the XXIV Indian Scientific Expedition to Antarctica

(2004 - 2005). In place of working in complete range from 300 Hz to 22 kHz we have used data upto the frequencny range upto 5 kHz for the ELF-VLF emission study. We have observed large number of periodic and quasi periodic and hiss emission in this range.

Atmospherics and Tweek Atmospherics

Lightning strokes thousands of miles away from the observer, produces short impulse which produces click sound, these impulses are known as "sferics" or "Atmospherics" Atmospherics is considered to be a very important component constituting the terrestrial electromagnetic environment in the lower frequency range. At times when the reflection efficiency of the ionosphere is high, this impulsive radiation may echo back and forth between the boundaries of the earth ionosphere waveguide many times before disappearing into the background noise. (Outsu, 1960; Budden 1961; Helliwell, 1965; Wait, 1972) and they were used to study the characteristics of distant lightning and also the lower ionosphere (Al'pert et al. 1970). Most of the lightning energy is radiated in the Extremely Low Frequency (ELF, 3-3000 Hz) and Very Low Frequency (VLF (3-30kHz), with the peak spectral density of these atmospheric (or sferics) being below 15 kHz (Volland et al.,1987; Ramachandran et al., 2007).

The duration of sferics is very short, in a range from few tens of ms to about 100ms, and the frequency change over this duration is as fast as ~10 kHz. Atmospherics are the strongest and most pervasive form of ELF-VLF radio noise. Generated by lightning in up to 2000 thunderstorms in progress around the world at any time (e.g., Chalmers, 1967), these atmospherics so completely dominates the natural ELF-VLF noise spectrum that the long – term statistics of noise contain essentially no contribution from the other form of natural ELF-VLF radio noise (Watt, 1967). An exception is at high latitudes, where the noise statistics for the frequency range 0.5 to 1.5 kHz may have significant contribution from polar chorus.

Due to distant lightning the received disturbance consists of a series of impulses, which produces faintly musical or chirping sound. This type of atmospherics is known as "Tweeks" or "Tweek atmospherics" (Helliwell, 1965). Tweek atmospherics are ELF-VLF waves which are observed very frequently all over the whole year (Outsu, 1960); they are utilized to investigate the lower ionosphere and to locate the lightning by using the tails of tweek atmospherics. If both the tweek atmospherics and whistler are included, then the distinction of the two is certainly not clear. Tweek atmospherics normally terminates at the frequency of about ~1600 Hz and it varies slightly depending on the latitude also, the duration of observed emissions suggests that whether it is tweek or whistler. The spectrum of the tweek atmospherics is hook shaped and depends on the distance from the source and height of the reflection. Dispersion exhibited by tweek atmospherics are due to the earth – ionosphere waveguide, and does not relates directly to the electron density of the ionosphere (Helliwell, 1965). Tweek atmospherics are used for the remote sensing of the ionospheric height (lower ionosphere).

Theoretical Consideration of Tweek Atmospherics under the Magnetoionic Theory

Ionosphere being ionized medium the refractive index varies with altitude and latitude. The refractive index of wave propagation in magnetoactive plasma is expressed by the Appleton-Hartree formula. (Budden, 1961). n_r is the refractive index expressed by the dimensionless quantities X,Y and Z

$$n_r^2 = 1 - \frac{2X(1-X-jZ)}{2(1-jZ)(1-X-jZ) - Y_T^2 \pm \sqrt{4Y_L^2(1-X-jZ)^2 + Y_T^4}} \qquad ...(1)$$

where X,Y and Z are ratio between wave frequency and the characteristics of the medium.

$$X = \left(\frac{\omega_p}{\omega}\right)^2 \qquad ...(2)$$

$$Y = \frac{\omega_H}{\omega} \qquad ...(3)$$

$$Z = \frac{v}{\omega} \qquad ...(4)$$

Y is divided into longitudinal and transverse component

$$eY_L = Y\cos\alpha \qquad ...(5)$$

$$Y_T = Y\sin\alpha \qquad ...(6)$$

where ω is the angular frequency of the wave, v is the angular collision frequency of electrons with neutrals, α is the angle between the propagation direction of the wave and the external magnetic field vector , ω_p is the angular plasma frequency is given by the following plasma frequency,

$$\omega_p = \sqrt{\frac{N_e e^2}{\varepsilon_0 m_e}} \qquad ...(7)$$

as $\omega_{\mathrm{p}} (= 2\pi f_P)$ than , f_P is plasma frequency.

$$f_p = \frac{1}{2\pi}\sqrt{\frac{N_e e^2}{m_e \varepsilon_0}} \approx 9.0\sqrt{N_e} \qquad ...(8)$$

and the angular electron gyro-frequency ω_H is given as follows:

$$\omega_H = \frac{Be}{m_e} \qquad ...(9)$$

$$\omega_H = \frac{e\mu_0 H}{m_e} \qquad ...(10)$$

as $\omega_{\mathrm{H}} (= 2\pi f_H)$

$$f_H = \frac{e\mu_0 H}{2\pi m_e} \qquad ...(11)$$

where N_e is the electron density per cm3, e (=-1.602×10-19 C) is an electric charge, ε_0 (=8.854×10-12F/m) is permittivity in a vacuum, m_e (=9.109×10 31kg) is the mass of an electron,

μ_0 (=4π×10-7H/m) is permeability in a vacuum, and H is the geomagnetic field strength. In Eq. (1), the upper sign “+” in the denominator corresponds to ordinary mode (O-mode) waves, and the lower sign “–” corresponds to extraordinary mode.

The X value where η_r^2 becomes zero is given by the following equation, which shows wave cut-off without regard to propagation direction:

$$X = 1 \qquad \text{...(12)}$$

$$X = 1 \pm Y \qquad \text{...(13)}$$

Equations (12) and (13) represent O-mode and X-mode waves, respectively. The X-mode waves correspond to X = Y +1 when Y > 1($\omega_H > \omega$), and X= 1–Y when Y < 1 ($\omega_H < \omega$). Therefore, only X = Y+ 1 is used for ELF-VLF waves.

Estimation of Electron Density

To estimate the electron density at the ionospheric reflection heights i.e. lower ionosphere, we perform a qualitative analysis based on the propagation theory of radio waves in infinite, collisionless anisotropic plasma. The electron density N_e at the reflection height of tweeks atmospherics is derived from X=1+Y as follows:

$$N_e(/cm^3) = 1.241 \times 10^{-8} f_p \left(f_p + f_H\right) \qquad \text{...(14)}$$

$f_P (= \omega_\text{p}/2\pi)$ Corresponds to the cut-off frequency of the tweek atmospherics for the first-order mode, and is replaced by the cut-off frequency (f_c) in the following equation. Since we receive tweek atmospherics from lightning discharges occurred mainly in low-latitude and equatorial regions we take f_H = 1.3±0.2 MHz according to the International Geomagnetic Reference Field (IGRF) model. The first-order mode cut-off frequency of tweek atmospherics usually ranges in 1.5–2.5 kHz. Then, f_H f_p is satisfied, resulting in that the Eq. (6) is replaced as follows:

$$N_e(/cm^3) = 1.241 \times 10^{-8} f_c f_H \qquad \text{...(15)}$$

Reflection Height and Propagation Distance

The Earth Ionosphere waveguide is considered to be two dimensional and planar, with perfectly reflecting walls separated by a distance h'. At a fixed frequency the field in the waveguide can be decomposed into a sequence of independent field structures (i.e. modes), which propagate with different phase velocities. Each of these modes except TEM can be defined by its cutoff frequency. Under the waveguide theory, an electromagnetic wave of wavelength λ propagates between the two reflecting walls, if $\lambda/2 = h'$ where h' is the ionospheric reflection height. Hence tweek propagating under sharply bounded ionosphere height will have a low frequency cutoff such that $f_c = c/2h'$ where c is the velocity of light in free space.

$$f_c = c/2h' \qquad \text{...(16)}$$

f_{cn} for nth mode is given by (Budden1961, Yamashita, 1978)

$$f_{cn} = nc/2h' \qquad \text{...(17)}$$

$$h' = \frac{nc}{2 f_{cn}} \qquad \text{...(18)}$$

where c is the velocity of light in free space. When mode number (n) is considered

If $f > f_{cn}$ and the mode propagates with a group velocity v_{gn} given by (Ohtsu, 1960):

$$v_{gn} = c\left(1 - f_{cn}^2 / f^2\right)^{1/2} \qquad \text{...(19)}$$

The v_{gn} approaches zero as f approaches f_{cn}. No propagation occurs if $f < f_{cn}$, as the wave is strongly attenuated. Using the Equation (17), total distance d, propagated by the tweek atmospherics of the n the mode with a perfect conducting, the EIWG can be obtained as (Prasad, 1981):

$$d = \frac{|(t_2 - t_1)|(v_{gf1} \times v_{gf2})}{v_{gf1} - v_{gf2}} \qquad \text{...(20)}$$

where $(t_2 - t_1)$ is the difference in arrival times of the two frequencies,

f_2 and f_1, close to of the tweek atmospherics of any mode; and are the corresponding group velocities of the waves centered at frequencies f_1 and f_2.

The ELF-VLF wave receiver experiments carried out at Indian Antarctica Research Station "MAITRI" is successfully applied to investigation of radiowave propagation in the Earth- ionosphere waveguide.

EXPERIMENTAL SETUP

Data recording setup is fundamentally a data acquisition system for acquiring the naturally occurring signals so that they can be regenerated or measured, analyzed and represented later on. A typical system may consist of individual sensors with necessary signal conditioning, multiplexing, data conversion, data processing, data handling and associated transmission, storage and display system. System consists of thin wired antenna, pre-and main amplifiers and DAT with computer systems. The thin wired vertical dipole antenna of 24 mts height for Tweek Atmospherics and triangular loop array antenna with each loop having an area of 144 m^2, height of 12 mts. Pre- and main amplifier which performs signal conditioning and impedance matching between antenna output and transmission cable. Both the pre and main amplifiers are adjusted to have a flat response in the frequency range 500 Hz to 12 kHz. We have regenerated recorded data in spectrograms.

RESULTS AND DISCUSSION

Present works is about the the results of ELF–VLF emissions study and Tweek Atmospherics study carried out at the Indian Antarctica Station "MAITRI" during the post–summer (polar) duration (January, February and March) of the year 2005. We observed interesting records of emissions activity of periodic nature at 4 kHz and quasi periodic nature below 2 kHz (at ~ 1250 Hz) as shown in **Figures 1 to 4**. These observed emissions are of Hiss types showing quasi periodic nature associated with periodic signatures too. Periodic structure is observed on quite as well as on moderated days. The recorded result of 13th February 2005 shown in **Figure 1**, the Kp sum was 7+. In the **Figures 2, 3 and 4** emissions recorded on 9th February, 18th February and 7th March , 2005 respectively are shown and the respective Kp sum are 31-, 31∘ and 37∘.

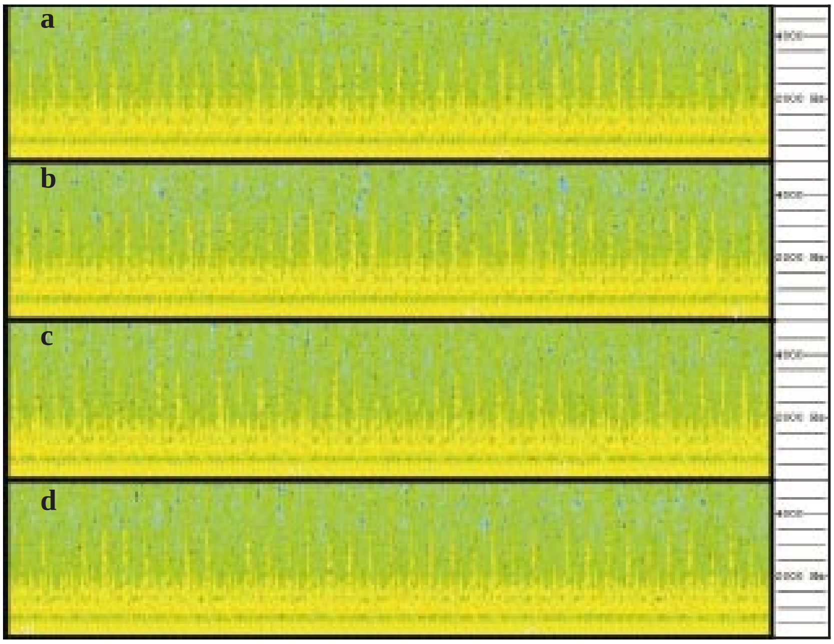

Fig. 1 : Quit time emission activity having periodic structure recorded at MAITRI 0530 UTC of 13th February 2005

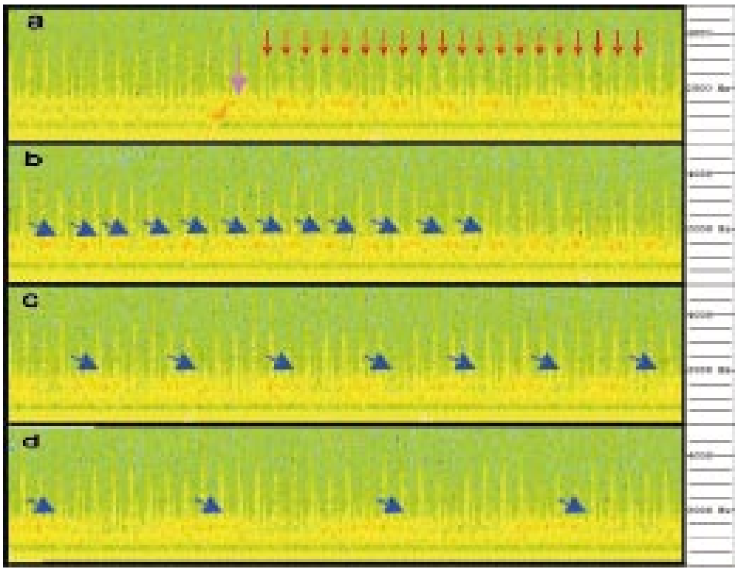

Fig. 2 : Hiss emission associated with periodic structure recorded at MAITRI at 1900 UTC of 9th February 2005

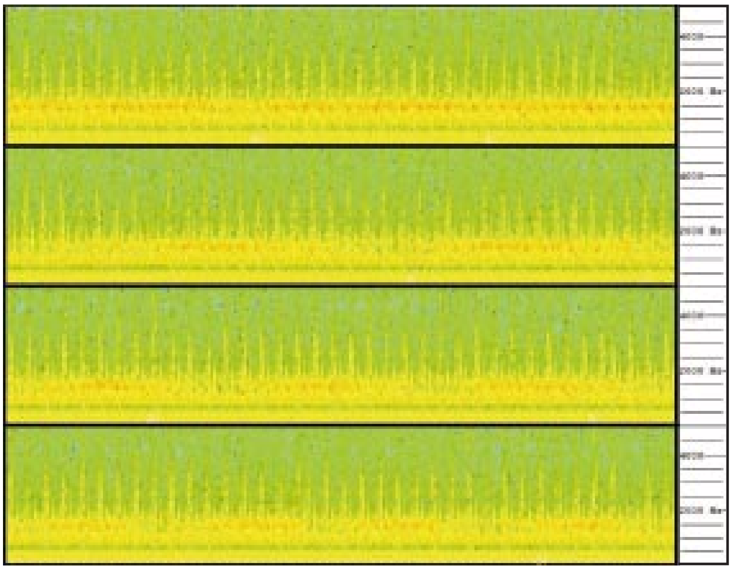

Fig. 3 : Hiss emission associated with periodic structure recorded at MAITRI at 0200 UTC of 18th February 2005

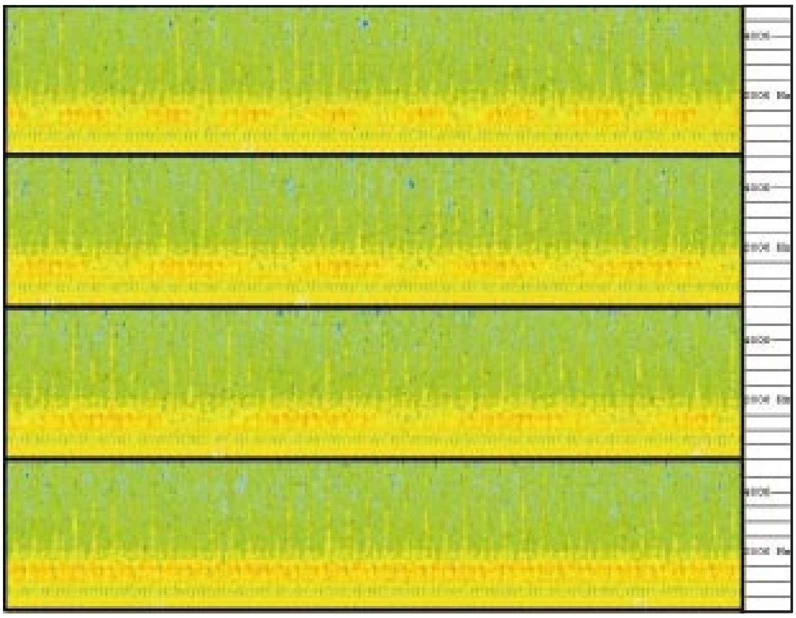

Fig. 4 : Hiss emission associated with periodic structure recorded at MAITRI at 0030 UTC of 7th March 2005

Sato et al. (1990, 1991), studied seasonal and long-term variations of daytime ELF-VLF emissions at two nearly conjugate auroral zone stations: Syowa in Antarctica and Husafell in Iceland. They used three frequency bands (750 Hz, 2 kHz, and 4 kHz); and found a maximum emission occurrence at 750 Hz during local summer in both hemispheres. But at MAITRI we have seen that maximum emission is at ~ 1250 Hz. Earlier studies show a close relationship exists between auroral hiss emissions and the visible aurora (Martin,et al., 1960; Makita,1979; Helliwell and Morgan, 1960; Rosenberg, 1968; Troitskaya and Kleimenova, 1972; Swift and Kan,1975 Srivastava 1976; Nishino et al., 1981). The most convincing results concerning the relationship between auroral hiss and aurora came from the investigation of the auroral hiss arrival direction (Makita, 1979; Tanaka et al., 1976; Okada et al., 1977; Hayakawa et al., 1981). There is a strong dependence of the hiss emission on Kp index increased from index. At Syowa station hiss occurrence increased when the Kp index increased from 0 to 5 and decreased when Kp index increased further. Similar features were observed by Hayakawa et al. (1975) and Tanaka et al., (1976). In our work we have not seen too much visual aurora, but we have compared some of the recorded event with the magnetic activity at "MAITRI", which shows enhancement of ELF-VLF periodic and quasi-periodic emissions at the frequency range below 4 kHz. The amplitude of the emission frequency fluctuates in a periodic or quasi-periodic manner with periods ranging from less than a second to more than a minute. The intensity of emissions is comparable to that of whistlers. Quasiperiodic ELF–VLF emissions in the frequency range from 100 Hz to 10 kHz with periods in the range 520s similar to pulsating aurora and spike type intensity variations are reported (Helliwell, 1965). At MAITRI we have seen that chorus observation is not a new thing, but here we are presenting such emission observed on 21st January 2005 at 2300 UTC, event is important as it is observed after the sudden storm commencement of 21st January 2005, during the time of strong magnetic activity. Midnight sector had been considered to be an especially interesting region for chorus because chorus is generated during magnetic sub-storms (Hayakawa et al., 1984), thus the results which we have shown is in support of our findings. Chorus has been interpreted as being generated by sub-storm electrons and an-isotropic loss cone distribution and the experimental aspects are well explained by the theory of electron cyclotron instability (Hayakawa et al., 1984; Goldstein, and Tsurutani, 1984). According to Hayakawa,(1993), the wave normals of the rising tone chorus take very small angles (5° -20°), give further support to loss cone instability as the generation mechanism. At mid and high latitudes the observed correlations between chorus emissions and energetic electrons suggest that these electrons play a key role in the generation of VLF emissions (Rosenberg et al., 1981). Brice (1964) suggested non convective transverse instability between whistler waves and counter streaming energetic electrons as basic mechanism for the generation of chorus emissions. This was an indirect evidence of relationship of ELF-VLF waves with magnetic activity due to high energetic precipitation.

The qualitative analysis of the observed tweek atmospherics shown in **Figures 5-6**. From the Equation (18) we have estimated the ionospheric reflection height of Tweek atmospherics using the waveguide mode theory of electromagnetic wave propagating in Earth-ionosphere waveguide having perfectly conducting boundaries having the low frequency cutoff. Figure 7 shows the ionospheric reflection height at Indian Antarctica Research Station "MAITRI" during the month of January, February and March of year 2005, it is found that reflection height ranges from 64 – 79 kms with a maximum calculated error ±2.7 kms in height and ± 62 Hz in. The waveguide dispersion, in frequency-time spectrogram asymptotes to the transverse resonance frequency of the waveguide, which is equal to the cutoff frequency (Nickolaenko and Hayakawa, 2002). But the analysis of tweek atmospherics observed at "MAITRI" shows that the average cutoff frequency for the fundamental tweek varies from January to March. On plotting the computed ionospheric virtual height from January to March, we saw increase from January to March as shown in **Figure 7**. The multiple harmonics tweek atmospherics are observed from the end of February. The finite conductivity of the earth ionospheric waveguide boundaries results in appreciable dispersion at the lower frequency end with the cutoff of above and equal ~1.8 kHz as of high latitude station. Thus Tweek atmospherics can be used for remote sensing the lower ionosphere. At night, when earth-ionosphere waveguide is highly conducting, the energy of an atmospherics reflects between the earth and the ionosphere with relatively little attenuation. We have carried out our recording at "MAITRI" during polar day time, which corresponds to night time in equatorial and tropical region. Due to this variation tweek atmospherics that were recorded are sometimes observed in broken spectral form. The group delay increases as the number of reflections increases, giving rises to train of pulses at the receiver. Thus the ionospheric reflection height observed from January to March increases. The intial study in varation in the lower ionospheric reflection height at MAITRI was reported in, Saini and Gwal (2010).

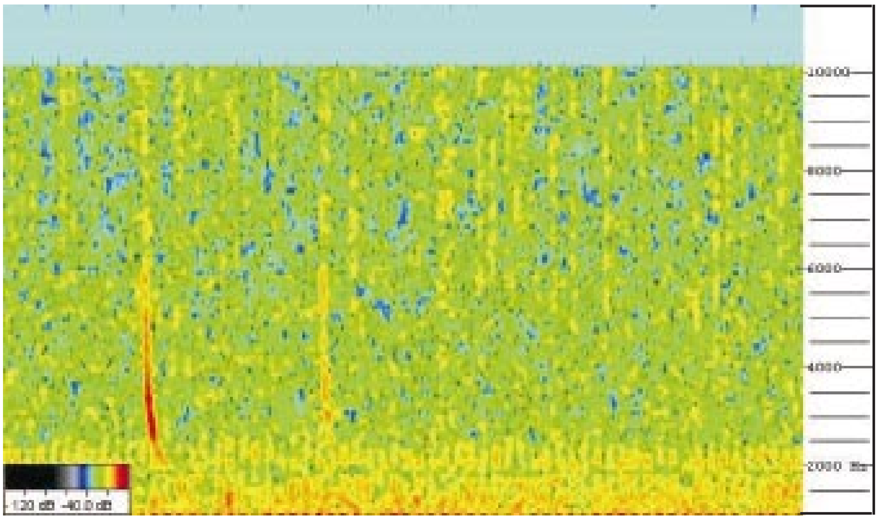

Fig. 5 : Spectra of fundamental tweek and its associated Atmospherics obtained from Spectrum Laboratory online recoding (Complete spectrogram is of 2 sec resolution)

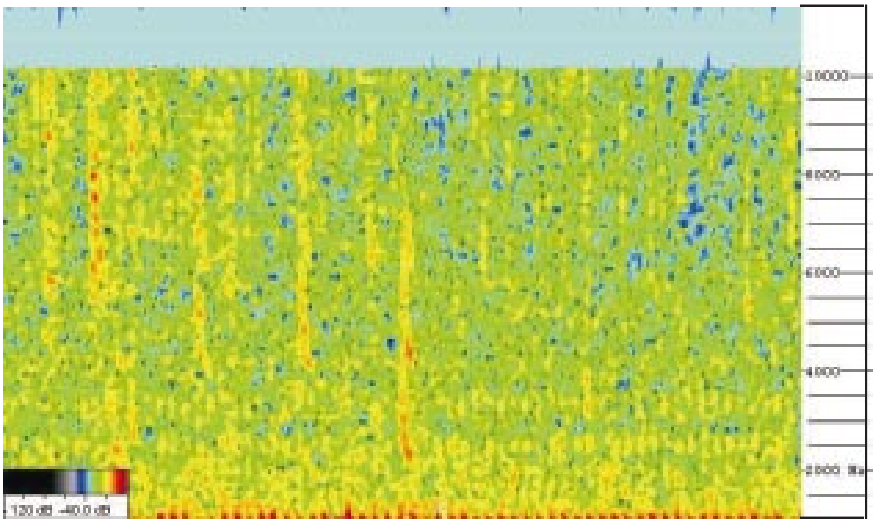

Fig. 6 : Spectra of fundamental tweek with second harmonics and its associated Atmospherics obtained from Spectrum Laboratory online recoding (Complete spectrogram is of 2 sec resolution)

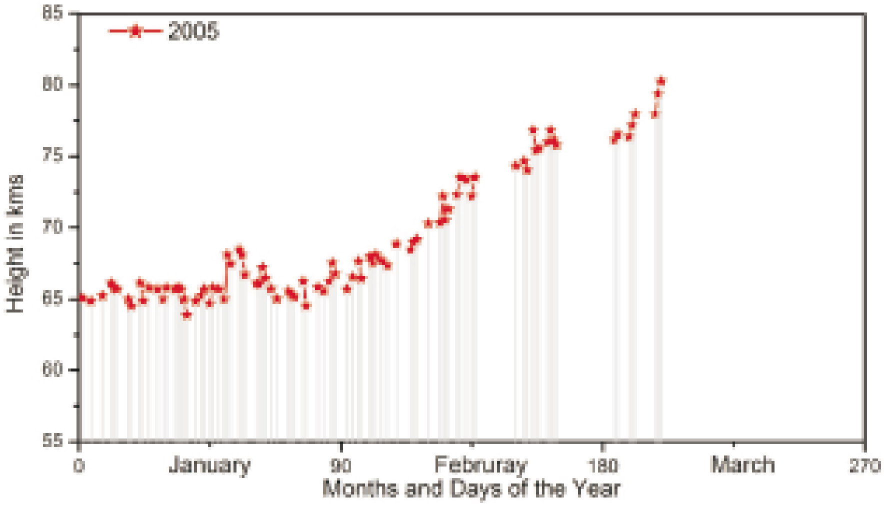

Fig. 7 : Variation of Ionospheric reflection height from January to March 2005

Photochemical equilibrium depends on ionization rate which is directly related to sun's zenith angle. It is expressed as (Rishbeth and Garriott, 1969)

$$q = (1+\lambda)(\alpha_D + \lambda\alpha_i)[e\}^2 = \alpha_{eff}[e]^2$$

Where q is the ionization rate, λ is the concentration ratio of negative ions to electrons, α_D is the dissociative recombination coefficient (weighted over the different types of positive ions present), α_i is the ion-ion recombination coefficient, and α_{eff} is an effective recombination rate. When electron densities are estimated with the help of equation (15) it is about N_e = 23.9369 to 30.71475 el./ cm^3 for the change of f_H, if we take f_c = 2.0 kHz. We have seen that for the period from January to March electron density falls and electron density with IRI 2001 model also shown falling trend at various height from 65 km to 75 kms January to March shown in **Figure 8**.

SUMMARY & CONCLUSION

The analysis of periodi and quasi periodic ELF-VLF Hiss emissions were presented in this paper observed at "MAITRI" Indian Antarctic Station reveals following facts. The observed Hiss is dependent on the Kp index

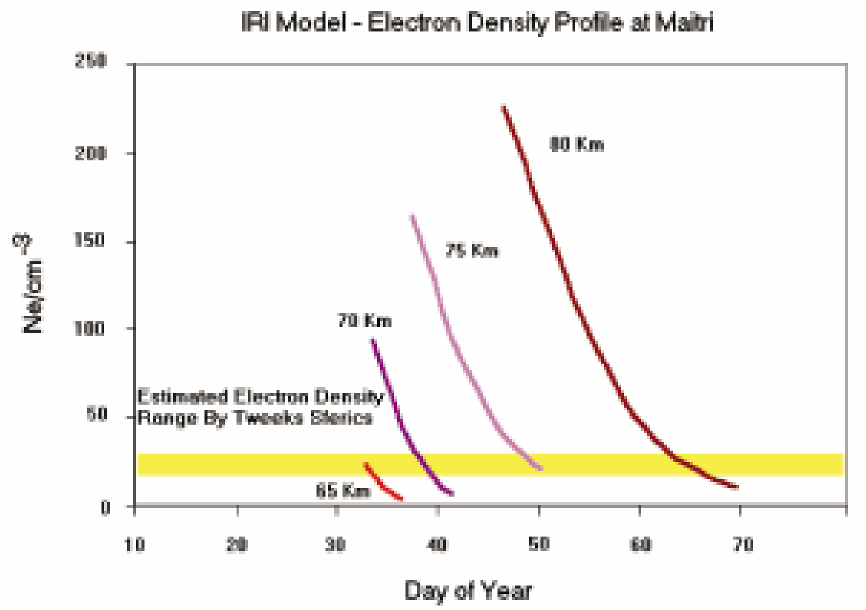

Fig. 8 : Electron density falling trend at various height at MAITRI (Taken from IRI 2001 Model) from the Height of 65 to 80 km. Yellow Band indicates the estimated electron density by Tweek atmosferics

where as periodic emission shows less dependence as compared to hiss. On high resolution some hiss shows quasi periodic in nature and some continuous behavior. With this we infer that at the initial stage hiss shows quasi periodic nature and later on continuous nature at “MAITRI”. Periodic emissions shows non dispersive nature at “MAITRI” Spectral analysis shows that hiss ranges in the frequency range below 2 kHz and maximum intensity around ~1250 Hz. Further, detailed studies are needed to know the generation and propagation mechanism of daytime ELF-VLF emissions.

Investigation of wave characterstics of tweek atmospherics reveals that the tweek atmospherics can be used to track the day and night boundary, there is a vartiaion in lower ionospheric height and the calculated propagation distance shows that the lightning occurring in tropical and equatorial regions (Saini and Gwal, 2010). Higher harmonics tweek atmospherics were observed only from the later part of of February at “MAITRI”, which leads us to conclude that possibility of observing higher harmonics during the peak austral summer at polar latitudes is very rare.

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