Absorption of Atmospheric Radio Noise Field Strength (ARNFS) at Low Frequency (LF) during the Higher Magnetic Activity Index

***Barin Kumar De*, Pinaki Pal and Anirban Guha**

Department of Physics, Tripura University, Suryamaninagar, Tripura (West), P.I.N: 799130, India
E-mail: barin_de@yahoo.com, pinakipal@hotmail.com, anirban1001@yahoo.com

Abstract

Remarkable absorption in the Atmospheric Radio Noise Field Strength at 81 kHz during meteorologically clear days exhibits a good correlation with magnetic activity index $A_{P} > 30$. Precipitation of energetic particles in the polar atmosphere can give rise to formation of NOs which are transported to equator. Electron density in the D region may increase to several times. It produces an increase attenuation of LF radio wave. The absorption is found to be between 5 and 11 dB. The magnitude of attenuation increases with geomagnetic activity index Ap.

1. Introduction

Lightning can now be monitored continuously with reasonable cost over large regions by means of radio noise emitted during cloud discharges. The electromagnetic radiations from cloud discharge known as atmospheric radio noises or atmospherics (abbreviated as sferics) are significant in regards to the electrical phenomenon going on in different types of cloud. In India researches on atmospherics have been performed from time to time but in a discrete manner. In Tripura we are in privileged position to study Atmospheric Radio Noise Field Strengths (ARNFS) from local and distant cloud discharges. During clear days ARNFS exhibits systematic variations over a day.

During clear period atmospheric radio noise field strength (ARNFS) measurement provides the study of ionospheric propagation. The variation of electric field ΔE can be expressed as Fourier transform: $\Delta E(d,t) = \int a(d,\nu) \exp(i\nu t)\, d\nu$, where the inverse FT is given by $a(d,\nu) = \int \Delta E(d,t) \exp(-i\nu t)\, dt$ gives the amplitude of Fourier component due to thunder electric pulse at a distance d. Previous experiments showed that the peak of the Fourier components lies in very low frequency (VLF) range. The low frequency (LF) component, though smaller in magnitude compared to VLF component, exhibits more variations in dB scale during ionospheric irregularities. The received Fourier component at frequency ν at distance d can be expressed as $a(d,\nu) = G(\nu)\, W(d,\nu)$, where $G(\nu)$ is the called spectral source function and $W(d,\nu)$ is the wave guide transmission function. $W(d,\nu)$ is dependent on the conductivity parameter of the ionosphere which is again dependent on electron density. Any variation in conductivity parameter will result in variation in attenuation of LF radio waves.

2. Observation and Results

The ARNFS at 81 kHz in the absence of local cloud activity is characterized by sunrise (SR) and sunset (SS) effects. After the local sunrise the level of ARNFS decreases gradually to a minimum value. The level is low till it is mid-day. After mid-day the level rises gradually and it becomes maximum (Amax) at afternoon period. The level then decreases slightly during local sunset. After that the level shows a maximum (Pmax) at post-evening. The Figure1 has been produced by taking average of the days which were locally clear in the month of August-September, 1997 But during 43 days, during the period from January 1995 to May 1998, we observed remarkable absorption. All the days of absorption corresponds to days having magnetic activity index A_P greater than 30. The nature of the absorption is that level of ARNFS does not increase after mid-day as is observed in normal days. The normal value tends to be restored only at about midnight. During this period Solar Geophysical Data Book, issued by NOAA reported 58 days of $A_p > 30$. So we can say that 74% of days of Ap greater than 30 are associated with anomalous absorption in LF atmospherics. The range of maximum absorption in a day varies from 5 to 11 dB. The magnitude of maximum absorption increases with the increase of Ap. This is shown in Figure 2.

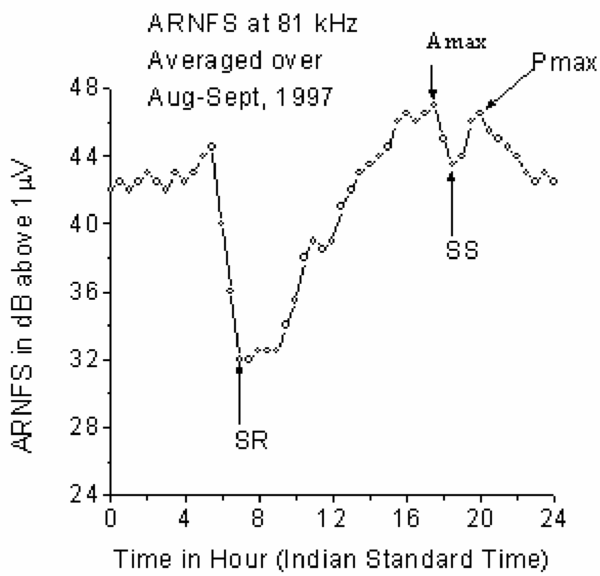

Figure 1: Diurnal variation of ARNFS

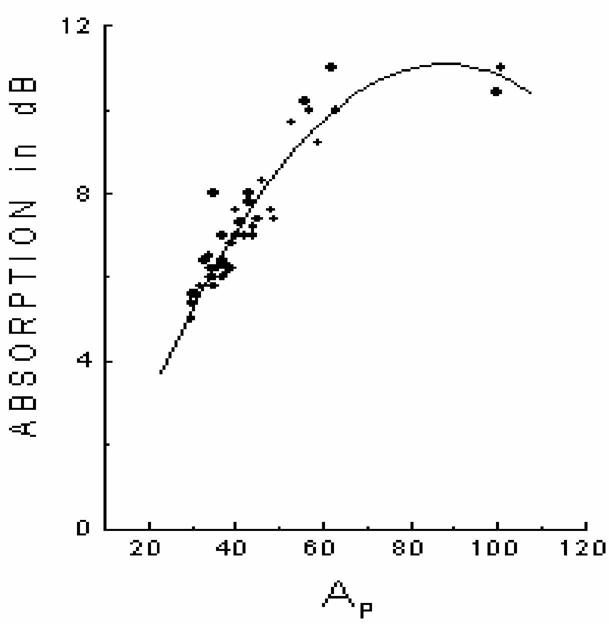

Figure 2: Variation of absorption with magnetic activity index Ap

3. Discussions

The propagation of LF radio waves is explained on the basis of two theories: the waveguide mode theory and the wave-hop theory. In both theories the resultant signal at the receiver depends upon the absorption coefficient which, in turn, depends upon the electron density of the absorption region below 70 km the gradual increase in signal strength after midday is certainly an indication of the gradual decrease of absorption below 70 km in the ionosphere.

Bracewell et al. [1] reported that the 16 kHz signal (GBR) from Rugby to Cambridge showed advances in phase and absorption in amplitude for several days after geomagnetic storms. Knuth and Lauter (1964) [2] studied strong enhancement in low frequency ionospheric absorption during and after very strong magnetic disturbances in the mid-latitudes. King and Fooks (1968) [3] observed that long lasting storm-after-effects in the ionospheric D-region caused marked absorption of the 245-kHz signal propagated over a distance of 600 km. Belrose and Thomas (1968) [4] reported that the VLF amplitude showed rapid fluctuations during geomagnetic storms and also anomalous diurnal variations during the days following the recovery of the geomagnetic field. Crary and Diede (1969) [5] noted the decrease in VLF signal strength in relation to the precipitation of energetic protons. Mendes et al. (1970) [6] reported the phase and amplitude changes of the VLF signal with reference to south Atlantic geomagnetic anomaly. Abdu et al. (1973) [7] reported a good correlation between VLF phase fluctuations and the variation in the horizontal component of the Earth's magnetic field during the main phase of the storms. Anomalous phase changes of transequatorial VLF radio waves during geomagnetic storms were reported by Araki (1974) [8]. Similar anomalies were reported at the mid latitude station by Hara and Horiai [9].Lauter and Knuth (1967) [10] argued that such long-lasting storm after-effects are not noticeable below latitudes of 50o. Beynon and Williams (1976) [11] reported that storm after-effects are not observable at latitudes below 48o. Dicinson and Bennet(1978, Kotadia et al (1981), Rastogi et al, 1982 and Huang and Cheng, 1993 [12-15] reported that lower ionosphere undergoes extra-ionization during geomagnetic activity. Satori (1991) [16] reported extra-ionization due to precipitation of energetic particles. Friedel and Hughes (1993) [17] reported that precipitation of energetic electrons can affect the low latitude D region.

The ARNFS at a measuring station are the combined effect of the variation of source activity and the prevailing wave guide conditions. Due to small E-region losses, the atmospheric radio noise levels at night depend on sources up to 10,000 km. In our study we have recorded the integrated effect from all directions. The variation of sources and prevailing wave guide conditions are the factors governing the nighttime mean level. The increase in electron density in the D region during geomagnetically active days gives attenuation of LF radio wave.

It was reported earlier that the lower ionosphere undergoes from extra-ionization during geomagnetic storms. At mid-latitudes (Satori, 1991) [16] the high energy particles can generally penetrate into the D-region down to the depth of about 75 – 80 km during geomagnetic storms. Sometimes high energy particles can even penetrate into the lowest D-region as shown by electron density measurements using partial reflection technique simultaneously with satellite observations. The upper boundary of the earth-ionosphere waveguide is formed by the lower edge of the ionospheric D region. The variation of the conductivity parameter (ω_r) due to extra-ionization during geomagnetic storms can affect radio-wave propagation. Here we emphasize the fact that this is the first report of the direct correlation of geomagnetic storms with signal anomaly in long-distance propagation from such a low-latitude station.

4. Conclusions

a) The level of LF ARNFS exhibit sunrise effect, sunset effect, afternoon maximum and post evening maximum.
b) The LF ARNFS exhibit anomalous absorption during higher geomagnetic activity periods $A_p > 30$.
c) The absorption occurs in the range of 5-11 dB and increases with Ap index value. The absorption persists only for one day.

5. References

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