"Variations of correlation coefficients of solar 2800 MHz flux and geomagnetic activity for the propagation of radio signals in perpendicular directions"

Pinaki Pal , Rousan Ali* and Barin Kumar De*
Department of physics, Belonia College, Belonia, South Tripura, 799155, India.
e-mail: pinakipl@yahoo.com

*Department of physics, Tripura University, Agartala, Tripura, 799130, India.
e-mail: barin_de@hotmail.com

Abstract:

The boundary of the lower ionosphere and the earth forms a wave guide for the propagation of the radio signal. The radio signal 19.8 kHz, which is being transmitted from North West Cape, Australia, and received at Kolkata, India have been analyzed shows that there is a variation of amplitude I relation to the solar 2800 MHz flux and geomagnetic storm activity. Another radio signal, 40 kHz which is transmitted from Sanwa, Japan is received at Agartala, Tripura, India, shows also the variations with the same physical parameters. But the variability coefficients are different for the two radio signals for which the propagation path is perpendicular to each other.

1. Introduction:

The spectrum of electromagnetic radiation below 100 kHz offers many interesting monitoring possibilities due to its unique characteristics. Here propagation is unusual because frequencies below 100 kHz have an additional characteristic of being able to travel long distance guided between earth and ionosphere [1]. The wave guide formed between the lower ionosphere and earth's surface is good for very low frequency (VLF) and low frequency (LF) propagation round the earth. The conductivity parameter determining the status of the ionospheric radio propagation is controlled by the solar conditions. It is well established that VLF & LF signals propagated over long distance exhibit diurnal variations due to temporal variation of electron density of lower ionosphere. Remarkable features are the so-called sunrise and sunset effects [1, 2].

2. Experiment:

The receiving system for the two receivers consists of loop antenna feeding a number of OP AMPs used in tuned radio frequency mode. The output of AC amplifier is detected with a time constant 0.22 sec and the DC level is further amplified quasi-logarithmically. A DC amplifier has been used to adjust the receiver's sensitivity corresponding to the incoming signal which shows marked variation over the year. The DC output is used as the signature of amplitude of 40 kHz. The receiver's band width is 200Hz, maximum gain120 dB, dynamic range 40 dB.

3. Observation, analyses and results:

The LF 40 kHz signal (Call Sign: JG2AS/JJF-2) which is being transmitted continuously from Sanwa, Japan ($36^o\ 11^/$ N, $139^o\ 51^/$ E) having radiating power10 kW & received in the department of physics, Tripura University, Agartala, India (23^oN, 91^oE) for the period from 1994 to 2000. The VLF 19.8 kHz signal (Call Sign: NWC) which is being transmitted continuously from North West Cape, Australia ($22^0 49^/$S, $114^0 10^/$E) having radiating power 1 MW, is received in Kolkata, India ($22^0 34^/$N, $88^0 24^/$E), for the period from March 1996 to February 1999. Both signals were received round the clock except for the period of local power failure and maintenance. Data of principal geomagnetic storms were taken from the Solar Geophysical Data Books issued by NOAA, US Department of Commerce. The analysis has been done by subdividing the whole year into four different solar phases. The different solar phases are Phase 1 (P1): June 21 - September 21; Phase 2 (P2): September 22 - December 21; Phase 3 (P3): December 22 - March 21 and Phase 4 (P4): March 22 - June 20.

The signal strength changes during geomagnetic activity in the low frequency (LF) and very low frequency (VLF) radio propagation have been successfully used to understand the ionization changes in the lower ionosphere. In this analysis the correlation between the signal amplitude and the geomagnetic A_P index has been found out. It revealed that the correlation co-efficient is dependent upon both time and solar phase. Here in the Fig. 1a & in Fig.1b the variation of the correlation coefficient with four solar phases for 19.8 kHz and 40 kHz amplitude respectively are shown.

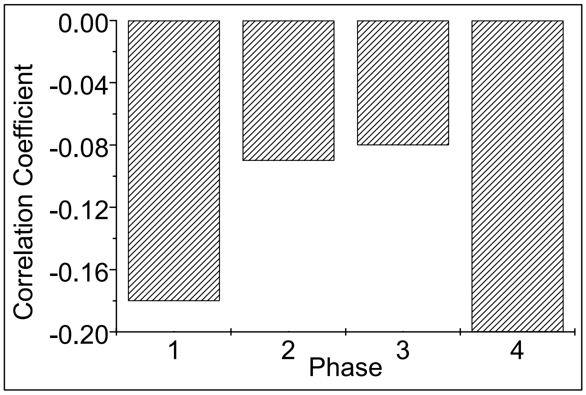

Figure.1a

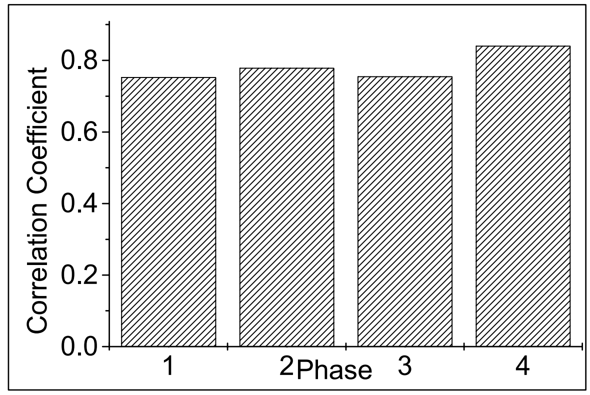

Figure.1b

It was expected that the long distance propagation in the earth-ionosphere wave-guide is to bear some relationship with solar flux at 2800 MHz. Here are the reports of the result of the analyses of amplitude of 40 kHz and 19.8 kHz radio signal in relation to solar radio flux at 2800 MHz. The normalized value of slowly varying components solar radio flux and the average value of amplitude of the signals, are plotted for positive and negative days (±7days) in the Fig. 2a (for NWC) & in Fig. 2b (for 40 kHz). In total 17 and 11 cases are considered or the NWC and 40 kHz signal which are depicted in Figure 3a and 3b respectively.

Although the correlation of propagation of signals with solar radio flux is dependent on the solar phases, for the NWC there is uncertainty in the coefficient of correlation. But the close correlation between solar radio flux and 40 kHz indicates a good sun-weather relationship throughout the year. The increase in solar radio flux is an indication of enhancement of all kinds of solar ionizing radiation over the earth's atmosphere. It can cause an increase in ambient electron density in the D-region of the ionosphere. The amplitude of 40 kHz radio wave in the spherical shell wave-guide formed by the earth as a lower boundary and the lower ionosphere as upper boundary is dependent on conductivity parameter given by—

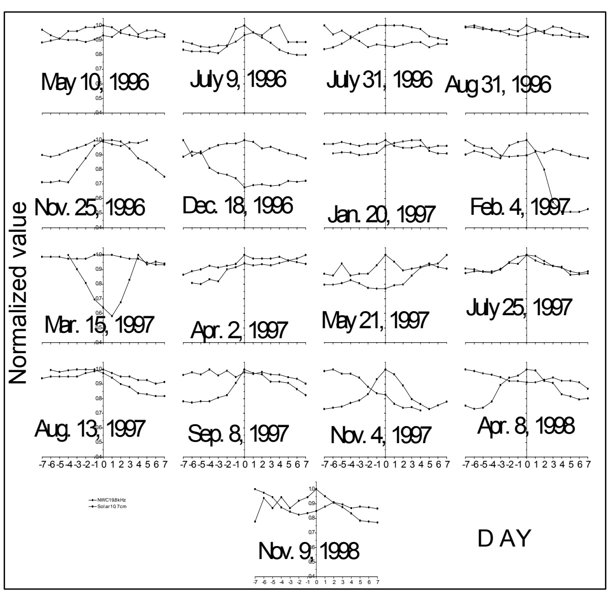

Figure 2a

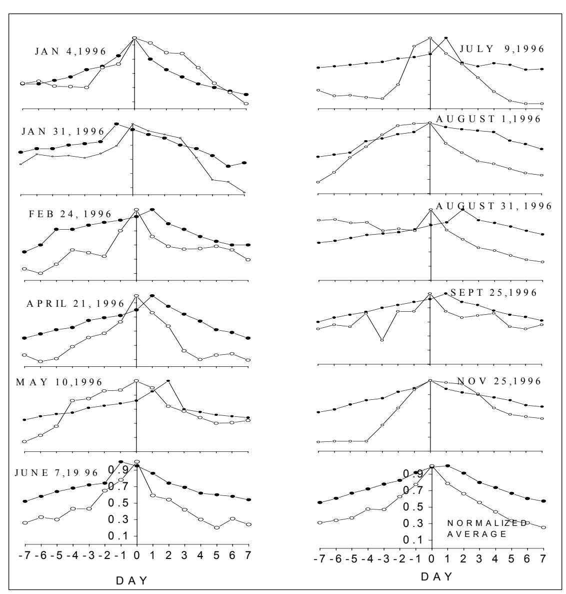

Figure 2b

$$\omega_r = \omega_0^2 / \nu$$

where ω_0 is the angular plasma frequency and ν is the collision frequency of electrons. The slowly varying component of solar ionizing radiation must give rise to a variation in ambient electron density in D region. This, in turn, can give rise to decrease in the overall attenuation of 40-kHz radio amplitude.

4. Discussion:

So, we see that the transequitorial propagation of VLF signal confined in the low latitude exhibits low but negative correlation with geomagnetic activity. The negative correlation between NWC signal amplitude and the geomagnetic activity index supports the fact that electron density in the region below 65 km enhances with the increase of magnetic activity. Since the presence propagation path if confined around the equator, the electron density level is not highly influenced. This is the reason of smaller magnitude of negative correlation coefficient. It is worth mentioning that only during the days of higher activity index, electron density of the absorption region is appreciably affected to give higher value of negative correlation coefficient.

The positive and good correlation between 40-kHz signal amplitude and A_P index can be understood from the knowledge of extra-ionization produced in the region below the ionospheric reflection zones. It has been reported that the ionospheric region below 85 to 90 km suffers from extraionization during the period of occurrence of geomagnetic storms. The excessive ionization is reported to start when the geomagnetic storm has its greatest intensity, i.e. when the decrease of horizontal intensity allows the high energy particles from the plasma cloud to invade the upper atmosphere in the geomagnetic latitude below 60^0 [3]. A tenfold increase in the electron concentration associated with geomagnetic storms has been reported by experiments with seven rocket flights Dickinson [4]. This enhancement took place in the altitude range 68 to 90 km. The phenomenon was reported to occur below 85 km in the early morning. Such an increases of electron density below 90 km have an appreciable effect on the 40 kHz signal amplitude.

During the recovery phase of Polar Cap Absorption (PCA) events, which is closely related to geomagnetic storms, electron density profiles show a very stable enhancement below 65 km [5]. The peak enhancement occurs at heights ranging from 62 to 65 km with electron density up to 3×10^8 to 4×10^8 m^{-3}. Such an electron density is greater than the normal D layer electron density of 10^8 m^{-3}. Now it is obvious that in such a case the LF signal under study must be reflected from the same height near 65 km at day and night. This kind of extra-ionization in the upper boundary of the earth-ionosphere waveguide causes a change to conductivity parameter ($\omega_r=\omega_0^2/\nu$) which in turn results in better propagational condition. The higher correlation coefficients in phase 4 may be due higher effect of electron precipitation in the ionosphere of northern hemisphere.

Acknowledgement:

The authors are thankful to S. K. Sarkar, ex- Professor, Department of Physics, Calcutta University for his constant encouragement in this work. One of the authors is thankful to UGC, India, for financial support through minor research project.

References:

[1] Courchley J and Rahmani Z , "Phase and amplitude variations of 40 kHz radio waves propagating over a 7.1 Mm path," J. Atmos. & Terrest. phys., 35, s.479-495, (1973).
[2] Sarkar, S K and De B K, "Meteorological effect on long distant 40 kHz signal," Arch. Met. Geoph. Biocl., 33A, s.365-379, 1985.
[3] Lauter E A, Knuth R, "Precipitation of high energy particles in to the upper atmosphere at medium latitudes after magnetic storms", 29, s.411-417, 1967.
[4] Dickinson P H G, Bennett F W G, "Diurnal Variations in the D region During A Storm After Effect", J. Atmos. & Terrest. Phys., 40, s.549-558, 1978.
[5] Rastogi P K, Brekke A, Holt O and Hanen T, "Variation of D region electron densities at Tromso", J. Atmos. & Terrest. Phys., 44, s. 313-323, 1982.