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The effects of recent solar eclipse upon a subionospheric transmitted signal

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Abstract : Continuous recording of a subionospheric transmitted signal at 16.4 kHz from Novik, Norway (66° 58´ N, 13° 54´ E) is being carried out in Kolkata (22° 34´ N, 88° 30´ E). The effects of recent solar eclipse on August 1, 2008 over this transmitted signal have been reported in this paper. The variations of normalized amplitude of this signal and its phase retardation in the path during the solar eclipse are measured which show significant deviations from their usual values for the same period of the control days.

Keywords : Solar eclipse, Subionospheric transmitted signal

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1. Introduction

Solar eclipse, solar flare, sunspot activity, geomagnetic event, Leonid meteor shower, nuclear explosion are mostly responsible for the observed changes in the subionospheric transmitted signals as well as VLF/ LF signals [1]. Solar eclipse gives researchers a unique opportunity to observe and analyse the dynamics of the Earth's space-environment. The spherical waveguide formed in the region between the earth's surface and lower concentric surface of the ionospheric D-layer maintains the propagation of subionospheric transmitted signal and VLF/LF signals. Signals coming from distant sources traverse through this Earth-ionosphere waveguide by multiple reflection. The strength of these signals depends upon the effective height of the ionosphere.

Amplitude and phase of VLF subionospheric and sferics signals are being monitored continuously from Kolkata (22° 34´ N, 88° 30´ E). These are directly influenced by global

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thunderstorm activity [2, 3], solar X-radiation and ionization of ionospheric constituents at the D-region of the atmosphere along with the conductivity of the medium.

Several earlier workers studied the effects of solar eclipse on VLF signal propagation through the Earth-ionosphere waveguide and measured their phase retardation [4-9]. Phase variations of VLF signal at 13.6 kHz from La Reunion (19° 31´ S, 57° 25´ E) and 16.0 kHz from Rugby (52° 21´ N, 1° 10´ W) were observed by Pant and Mahra (1994) during the solar eclipses on February 16, 1980 and July 31, 1981, respectively, at Naini Tal (29° 21´N, 79° 27´ E). They measured the phase delay of 8 μs for the signal of 13.6 kHz at Naini Tal [4]. Various atmospheric electricity parameters, *eg.*, potential gradient, conductivity, air-earth current and space charge density were measured during the solar eclipse period on March 18, 1988 at Pune (88° 34´ N, 73° 58´ E) [5]. Significant variations in phase and amplitude of VLF frequencies in the range 16 kHz – 24 kHz were reported by Clilverd *et al.* (2001) during the solar eclipse in Europe on August 11, 1999 [6]. Buckmaster and Hansen (1986) reported a phase retardation of 1.60 μs estimated during the total solar eclipse of February 26, 1979 on 60 kHz WWVB transmitted signal from Calgary (51° 03´ N, 114° 05´ W) [7].

During the solar eclipse of October 24, 1995, the absorption of radio waves was found to decrease. It was measured at frequencies 2.5 MHz and 2.8 MHz from Ahmedabad (23° N, 72° 36´ E) by Lele *et al.* [8] The reduction in the level of absorption from its normal values observed at 9.6 MHz transmitted signal from Taipei (25° 02´ N, 121° 31´ E) was found at Wuhan (30° 38´ N, 114° 17´ E) during solar eclipse on October 24, 1995 [9].

The focus of the present work is to observe and examine the effects of solar eclipse of August 1, 2008 on the earth's upper atmosphere by observing the changes in the transmitted subionospheric signal. The results obtained by the analyses of the observed data from continuous recording at Kolkata of the subionospheric signals transmitted from Novik, Norway (66° 58´ N, 13° 54´ E) at 16.4 kHz frequency on the day of recent solar eclipse on August 1, 2008 has been presented. The great circle distance of the transmitting station of Norway from Kolkata is about 7037 km. The variations of normalized amplitude and the phase retardation over the long path during the period of solar eclipse are shown graphically.

2. General information of the eclipse and weather

The eclipse of August 1, 2008 started at 16:18 hr LT and continued upto 18:05 hr LT, which was visible partially (maximum about 55 %) from Kolkata throughout the period. The local sunrise and sunset period were 05:10 hr and 18:16 hr, respectively. The temperature was 32.8° C at the start of the eclipse which gradually fell to 29° C towards the end. The relative humidity was 89 % at the start and increased to 95.5 % towards the end. The sky was clear at the beginning of the eclipse and it remained clear about 70 minutes period from the start, then it became cloudy. Some rainfall occurred towards the end. The sun was visible after the end of eclipse till sunset time at 18:16 hr LT.

3. Instrumentation and the methods of observations

A very long (about 120 m in length and 8 SWG copper wire) inverted L-type antenna is used to receive the vertically polarized signals which are fed to a signal processor tuned at 16.4 kHz. It is installed horizontally at a height of about 30 m above the ground. The overall Q-factor of the tuning circuit is around 300. The signals from the tuning stage are fed to a log amplifier. The recording, processing and storing of data are carried out by computerized method through data acquisition system.

4. Results and discussions

The propagation path of the 16.4 kHz subionospheric signal from Norway to Kolkata is indicated in Figure 1 by the line PQ. The eclipse was visible partially throughout the whole path and it was about 55 % visible from Kolkata. The totality is shown by the line AB. The line CD indicates the visible zone upto 60%.

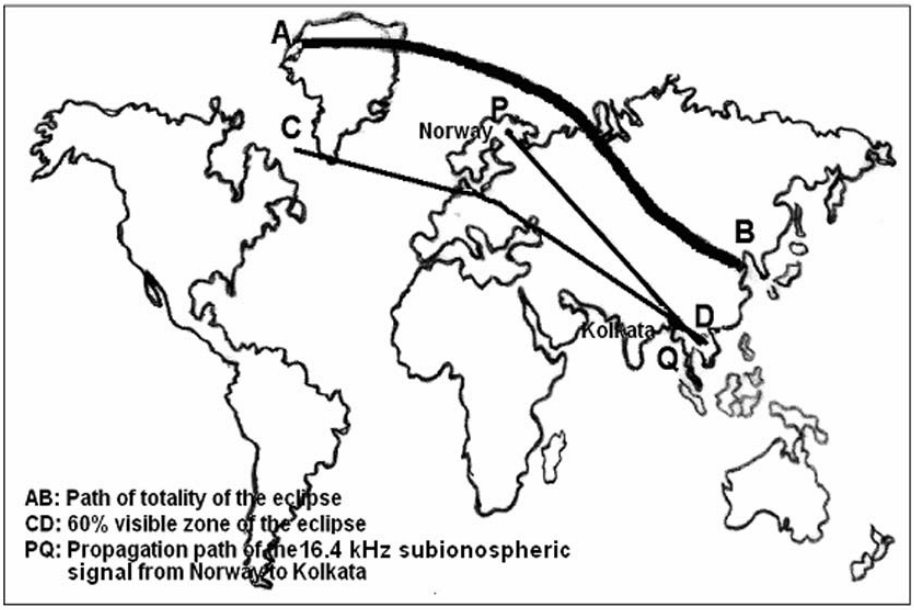

Figure 1. The propagation path of 16.4 kHz subionospheric signal from Norway to Kolkata has been marked by the line PQ. AB is the path of totality. The line CD illustrates the boundary for 60 % occurrence.

Figure 2 shows a significant variation in the normalized amplitude of 16.4 kHz signal on August 1, 2008 during the solar eclipse (continuous line). Broken line represents the values of normalized amplitude averaged over other five days adjacent to the date of occurrence. Standard deviations of normalized amplitude of the signal on August 1, 2008 from the average value are plotted as error bars. Higher enhancement of normalized amplitude prior to the time of occurrence of the solar eclipse may be attributed to the development of convective instability initiated by changes in the intensity of the solar radiation due to eclipse. During the eclipse period, the increase of normalized amplitude from the average value may be due to changes in ionization and conductivity of the medium.

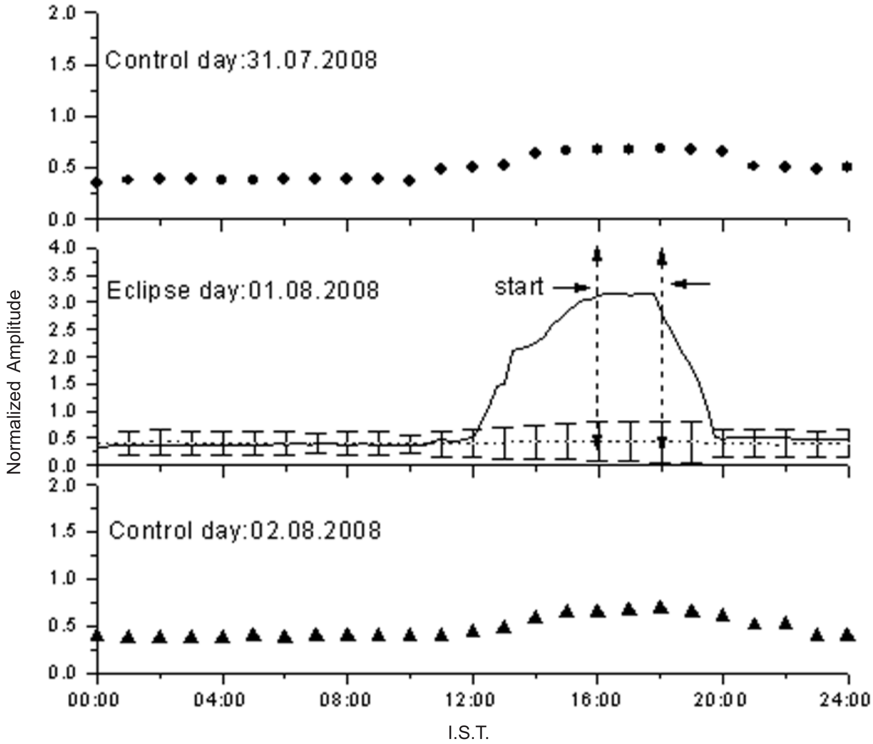

Figure 2. Normalized amplitude of 16.4 kHz signal during solar eclipse along with its averaged value for the adjacent five days. The standard deviations from the average value are given by error bars. The plots of normalized amplitude on a day around the day of eclipse are also shown.

Phase retardation observed over the propagation path due to solar eclipse is depicted in Figure 3. It shows a maximum of 6.6 μs. During the period of solar eclipse, solar flux reduces which decreases the ionization rate of the ionospheric constituents resulting in D-region height enhancement. The observed phase delay may be due to changes in the medium characteristics resulting from the decrease of ionization and conductivity.

5. Conclusion

The effects of solar eclipse on VLF signals were reported by earlier workers [4-6,10]. Some common trends are observed in their characteristics. The outcome of the results of our observations on the subionospheric transmitted signals during the solar eclipse on August 1, 2008 is presented here. We conclude that the waveguide mode propagation of long distance VLF transmitted radio signal exhibits small delay in phase followed by enhancement of amplitude. The results may be established by Earth-ionosphere waveguide mode theory considering perturbations on some involved parameters, *eg.,* attenuation factor, Fresnel's reflection coefficient, conductivity of the medium, angular plasma frequency and collision frequency due to effects of solar eclipse.

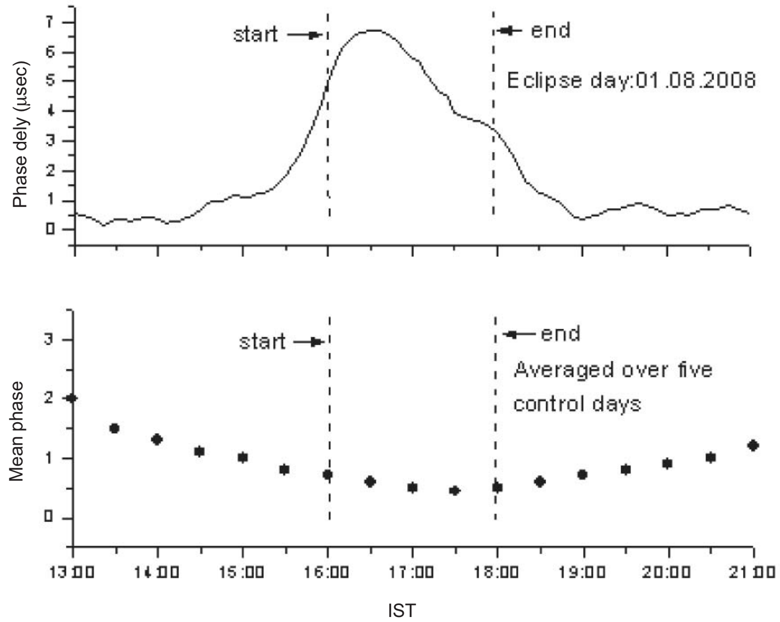

Figure 3. Phase retardation of 16.4 kHz signal in the propagation path as measured from Kolkata. Mean phase averaged over five control days is also depicted.

Reduction in the values of meteorological variables, like temperature, global radiation, humidity, wind speed are prominently measured during the solar eclipse of March 29, 2006 in Greece [11]. Due to perturbation of temperature causing stabilization of the atmospheric boundary layer during the eclipse, surface wind speed was found to decrease. Recent observations indicate a deceleration of the mean wind flow during a solar eclipse [12-15] and this is attributed to the combined effect of the decrease of the thermal gradient, the stabilization of surface layer following the drop of temperature and the suppression of turbulent processes.

In general, the temperature drop becomes noticeable when the sun is about half-covered. Szalowski (2002) reported an immediate temperature response while according to Narasimha *et al.* (1982), the response was at the end of the eclipse [16, 17]. The pattern and amplitude of the temperature drop is different for each location and can vary from less than one to several degrees depending on many factors. The percentage of sun coverage, the latitude, the season and time of the day, the synoptic conditions, the height of measurements, topography, degree of atmospheric pollution, vegetation, soil conductivity account for the different patterns of the temperature fluctuations during a solar eclipse. The time lag between the occurrence of the temperature minimum and the totality (or the maximum partiality) is a result of the thermal inertia of the air and the ground.

In the present observation, the temperature decrease showed maximum at 16:55 hr LT when 55 % were covered.

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