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Anomalous Behaviour of 22.3 kHz NWC Signal during Total Solar Eclipse of October 24, 1995

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Abstract

The effect of total solar eclipse of October 24, 1995 on long distance VLF radio wave propagation of 22.3 kHz from North West Cape, Australia to Calcutta is being reported here. After the commencement of the total eclipse the signal exhibited small attenuation followed by a recovery and a sudden enhancement to a value comparable to seasonal maximum. After the eclipse the signal returned to almost normal value by a sudden fall. The observation is closely related to the changes of electron density of the lower ionosphere which behaves as the upper boundary of the earth-ionosphere waveguide.

Key Words : Solar eclipse, VLF propagation, Lower ionosphere, Waveguide mode theory

Introduction

It is well known that the space between conducting earth's surface and the lower boundary of the ionosphere behaves as a waveguide (Sao, *et al.*, 1970; Wait, 1982; Sukhorukov *et al.*, 1992) towards the propagation of VLF radio wave. The changes of the electron density of the D-region cause the variation of upper boundary reflection coefficient of the wave guide. During solar eclipse the ionosphere experiences sunset- and sunrise-like transitions successively within 2-3 hours. So, during solar eclipse VLF radio wave may exhibit characteristic variations identical to that expected during sunset and sunrise. In this paper we report an anomalous behaviour of 22.3 kHz NWC signal transmitted from Australia and received at Calcutta during the total solar eclipse of October 24, 1995.

Experiment and Observations

We are monitoring the 22.3 kHz NWC radio signal at Calcutta (22° 34' N, 88° 24' E) round-the-clock. The NWC signal transmitted from North West Cape (22° 49' S, 114° 10' E), Australia is radiated at 1 MW. The great circle distance between the receiving and the transmitting station is 5.7 Mm. The VLF receiving system comprises of a tuned loop antenna. The voltage induced at the antenna is fed to an AC amplifier followed by a series resonant circuit at 22.3 kHz. It is then detected and the detected output is fed to a logarithmic amplifier (LOG AMP) to increase dynamic range. The output of LOG AMP is further amplified and its output is used to drive a chart recorder at a speed of 2 cm s^{-1}. The recording time constant is 7.5 s.

The path of totality crossed the almost N-S VLF propagation paths from West to East. The entire path was in the day region of the earth before and after the eclipse. The commencement time of the solar eclipse at Calcutta was 07:32 IST. The eclipse ended at 10:17 hrs at Calcutta, but the total time of duration over the propagation path was 3 hour 25 minutes.

The NWC signal behaved anomalously during the period of solar eclipse of October 24, 1995. In Figure 1 we have reproduced the actual amplitude record during the solar eclipse together with the previous day's record of the same time of the day. At 07:45 hrs, IST after the beginning of the solar eclipse at Calcutta, the signal level started decaying and it decayed by 7 dB within half an hour. From 08:15 hr to 08:45 hr the level remained constant at this low value. At 08:45 hr, IST signal level started rising gradually for the next 20 minutes by 6 dB. This was followed by a sudden enhancement up to the seasonal maximum by an amount of 13 dB. The signal level remained there for about an hour. At 10:15 hr, IST, the signal level exhibited a sudden fall followed by another small decay. The signal level ultimately came to the normal value as at around 11:40 hr, IST.

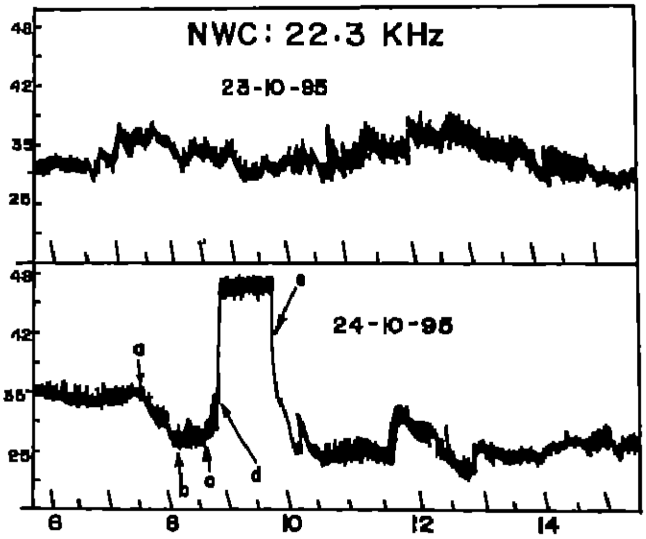

Figure 1 : Actual records of NWC 22.3 kHz radio signal. The upper one is a record of 23-10-95 which is previous to date of total solar eclipse. The lower one shows the record during total solar eclipse of 24.10.95 :

(i) a to b gradual fall, (ii) b to c constant level, (iii) c to d gradual rise,

(iv) d is sudden enhancement and (v) e is sudden decay of the signal

Time shown along X-axis is in Hour, IST and the signal level along Y-axis is in terms of the induced voltage at the antenna in dB above 1 μV.

Discussion

Studies on the changes of the ionosphere during a solar eclipse have been made earlier by many authors (Brace *et al.*, 1972; Chakraborty and Chakraborty, 1974; Jain and Subrahmanyam, 1979; Sen *et al.*, 1982). The main objective of their studies was to investigate how the cut-off of the solar ionizing radiations during the eclipse affects the different region of the ionosphere. But none of their study involved propagation over a large distance. The present observation may be achieved as an important perturbation on long distant waveguide mode propagation of VLF wave.

The attenuation factor (α_M) is given by

$$\alpha_M = -8.68 \ \{(2\pi)/\lambda\} \ I_m (S_M) \ \text{dB Km}^{-1}, \text{ where SM} = \sqrt{1 - C_M^2}$$

C_M being the root of the modal equation :

$$R_l \exp(-i\, k_0\, HC_M) = \exp(-i\, 2\pi M)$$

The Fresnel's reflection coefficient R_l is given by

$$R_l = \frac{(1 - i\,(\omega_r/\omega))^2\, C_M - ((1 - i\,(\omega_r/\omega))^2 - S_M^2)^{1/2}}{(1 - i\,(\omega_r/\omega))^2\, C_M + ((1 - i\,(\omega_r/\omega))^2 - S_M^2)^{1/2}}$$

where the conductivity parameter is given by $\omega_0^2 = \omega_0/\upsilon$, ω_0 being the angular plasma frequency, υ = the collision frequency.

Variation of electron density and hence conductivity parameter (ω_r) of the ionosphere may (Ferguson *et al.*, 1985) cause a variation of R_l. Due to decrease of electron density there arises a competition between two processes- (i) decrease of Fresnel's reflection coefficient giving rise to increased attenuation of the signal amplitude and (ii) decrease of absorption in the absorption layer below 70 km causing a decreased attenuation. At the beginning from 07:45 hrs to 08:45 hrs the first process dominated over the second and we observed a fade in signal strength. At a certain stage electron density became small enough that the second process dominated over the first and the signal amplitude started rising. At the peak phase of the eclipse the electron density of the D-region over the present propagation path became too small to reflect VLF wave at 22.3 kHz. The upper waveguide boundary shifted suddenly from D-region to lower E-region where Fresnel's reflection coefficient is much higher than that at 70 km because of lower collision frequency and hence higher conductivity parameter. This manifests a sudden rise of the signal. During decaying phase of the solar eclipse, photo-ionization process in D-region was restored and at a certain stage electron density of this region attained a value sufficient to reflect 22.3 kHz. The ionospheric waveguide boundary again returned to normal height of 70 km, and the signal level suddenly came to a value comparable to that in the initial phase of the eclipse. In conclusion we remark that the waveguide mode propagation of long distance VLF radio wave exhibits small decay followed by an anomalous enhancement of amplitude. The present work will be followed by a numerical analysis.

References

Brace L.H., Mayer H.G., Pharo M.W., Scot L.R. and Spancer N.W. 1972, J. Atmos. Terr. Phys., 34, 673

Chakraborty P. and Chakraborty D.K. 1974, Ind. J. Rad. Space Phys. 3, 319.

Ferguson J.F., Morfit D.G. & Hansen P.M., 1985. Radio Sci. 20, 528.

Jain S.L. and Subrahmanyam C.V. 1979, Ind. J. Rad. Space Phys., 8, 348.

Sao K., Yamashita M., Tanahashi S., Jindoh, H. and Ohta, K., 1970, J. Atmos. Terr. Phys., 32, 1567.

Sen A.K., Saha B., Trehan S.K., Dey S. Shekhar, Saha S.K., Dutta R.N., Chatterjee S.K., Sehra J.S. and Dasgupta M.K., 1982, Proc. Indian Nat. Sci. Acad., 48A, 302.

Sukhorukov A.L., Shimakura S. and Hayakawa, 1992, Planet. Space Sci. 40, 1363

Walt J.R., 1982, Electromagnetic waves in stratified media, Pergamon press, Oxford.