Vlf Phase & Amplitude Measurements during Solar Eclipse

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The measurements made by means of vlf phase and amplitude recordings made on 22.3 kHz (NWC, Australia) during the solar eclipse of 23 Oct. 1976 have been discussed. The phase and hence the reflection height were observed to increase gradually well after the first contact. The total change in the reflection height at the totality was found to be of the order 5 km. The recovery of the phase was somewhat gradual as compared to the onset. The variations in amplitude during the eclipse were not appreciable. The changes occurring in the phase of vlf signal during this event have been interpreted in terms of ozone and atomic oxygen concentration in the D-region of the ionosphere. The implications of the study in respect to the change in the ratio $\frac{N_d}{N_o}$ are explained.

1. Introduction

Recording of phase and amplitude of vlf stabilized transmission on 22.3 kHz from NWC, Australia (21°67'S; 114°16'E) is being done over a trans-equatorial path at the National Physical Laboratory, New Delhi (28°35'N; 77°13'E). The path length is 6850 km.

In this paper the effect of total solar eclipse of 23 Oct. 1976 on the D-region parameters has been discussed. Although New Delhi was out of eclipse path, however, more than half the path of NWC (Australia)-New Delhi fell in this eclipse path. In Fig. 1 the propagation path (i.e. New Delhi-NWC) and the eclipse conditions are shown.

2. Experimental Set-up

The purpose of the equipment used is to record phase and amplitude of frequency stabilized vlf signal. The technique is coherent detection, in which the received signal (22.3 kHz) from NWC, Australia, is compared with a voltage derived from a highly stabilized (5 parts in 10^-10) 105B HP 100 kHz oscillator. The system has been described in detail by Jain and Subrahmanyam.1

3. Results

The phase and amplitude measurements have been made during the total solar eclipse on 23 Oct. 1976. The variation of reflection height can be obtained by measuring the change in phase during the time of observation using the formula

$$\Delta h = -\frac{c\Delta t}{d\left(\frac{\lambda^2}{16h_0^3} + \frac{1}{2a}\right)}$$

which is a first order approximation,2 where $c$ Velocity of light $h_0$ Height of the ionospheric daytime reflecting layer (70 km) $a$ Radius of the earth $\lambda$ Wavelength of the transmitted vlf signal $d$ Distance between transmitter and receiver $\Delta t$ Phase change in sec

$$\Delta t = \frac{\Delta \phi}{0.36} \times 10^{-6} \text{ sec}$$

Fig. 1 — Passage of total solar eclipse of 23 Oct. 1976
JAIN & SUBRAHMANYAM : VHF PHASE & AMPLITUDE MEASUREMENTS DURING SOLAR ECLIPSE

![Graph showing reflection height versus time](image)

Fig. 2 — Comparison of eclipse (---x---x---) and quiet day (---o---o---) reflection heights at 22.3 kHz

\[ \Delta \phi \text{ Change of phase in degree} \]

\[ f \text{ Frequency of the signal} \]

The variation of reflection height thus obtained during the total solar eclipse is shown in Fig. 2. This change in reflection height has also been plotted in Fig. 3 along with the diurnal variation of the reflection height.

The amplitude variation during this period (eclipse period) did not show any significant changes and, therefore, has not been shown in the diagrams.

4. Discussion

It can be seen from Fig. 2 that the reflection height began to gradually increase well after first contact at D-region height and it became maximum a few minutes after the maximum solar obscuration. The recovery of phase is found to be somewhat more gradual than at the onset.

The magnitude of the phase advance produced by the eclipse is approximately 28°. This change in phase angle corresponds to a change in reflection height of about 4'8 km.

In Fig. 4 a comparison of the variations in phase height (reflection height) at the time of solar eclipse and at sunset period has been made by shifting the time scale of the phase changes during the eclipse making it coincide with the time of sunset. It is evident from Fig. 4 that the change in reflection height during eclipse is approximately one-fourth of the change in reflection height from day to night. It is clear from this illustration that the eclipse effect was only a fraction of the diurnal effect, which indicates that the ionosphere did not relax to night-time condition during the eclipse.

Doherty\(^4\) compared the phase change and the normalized ozone concentration for a period of four hours beginning at eclipse onset. The reaction rates measured by Fehsenfeld et al.\(^4\) have been used to explain the similarity of variation of ozone content and reflection height during the eclipse. The increase in \(O_3\) during solar eclipse may be attributed to the absence of the photodissociation.\(^5\) An increase in \(O_3\) would deplete \(O_2\) because of the fast reaction

\[ O_3 + O \rightarrow O_2 + O_2 \]

![Graph showing reflection height versus time](image)

Fig. 3 — Comparison of total solar eclipse (---x---x---x---) and diurnal (---o---o---o---o---) reflection height changes

![Graph showing reflection height versus time](image)

Fig. 4 — Comparison of total solar eclipse (---x---x---x---) and sunset (---o---o---o---o---) reflection height changes at 22.3 kHz

349
The variation of $\lambda$ with height is shown in Fig. 5. It is seen from Fig. 5 that the $\lambda$ is around unity at 70 km at onset of the eclipse and it is around unity at 74.8 km during maximum obscuration. This is in agreement with the value at 70 km with that of Taubenheim et al. and Mitra.

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References