1980BASI....8...69T

Satellite Radio Beacon Study of the Ionospheric Variations at Hyderabad during the Total Solar Eclipse of February 16, 1980

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(Received May 3, 1980; revised June 5, 1980)

Abstract

Preliminary results of observations, made on the eclipse day (Feb. 16, 1980) at Hyderabad, on the amplitude and phase of 136 MHz transmissions of the geostationary satellite ETS-II are presented in this paper. Apparently no Travelling Ionospheric Disturbances (TID'S) were generated by the eclipse. The percentage decrease in Faraday rotation showed an excellent correlation with percentage increase in optical obscuration of the Sun with a time lag of about 12 minutes.

No amplitude scintillations were observed on the night of the eclipse day, though there were strong scintillations on adjacent days.

1. INTRODUCTION

The Radio Science Division of the National Physical Laboratory (N.P.L.), New Delhi, installed a Satellite Radio Receiving System at the Nizamiah Observatory, Hyderabad (17.3° N; 78.5° E) to record the amplitude and Faraday rotation on 136 MHz transmissions of the Japanese geostationary satellite ETS—II. This is a two-channel double frequency conversion, phase lock radio receiving system. The equipment contains an automatic lock acquisition for both channels with monitoring outputs for earphones, lock-in indication by LED'S, displayed search range and universal outputs for both amplitude and phase chart recorders (Fuhrmann and Tyagi 1976). A 12—element crossed Yagi antenna has been used with this system. The system has been operated and maintained by the Centre of Advanced Study in Astronomy, Osmania University, Hyderabad, in collaboration with the N.P.L.

A total solar eclipse occurred over the Indian sub-continent on Feb. 16, 1980. The path of totality cut across the Southern Peninsula of the Indian sub-continent and the altitude of the Sun varied from 40° at the west coast to 16° on the coast of Bay of Bengal. The relevant features of this eclipse concerning the satellite beacon station at Hyderabad are given in Table 1. A preliminary account of the ionospheric changes measured with the Satellite Radio Beacon recordings and its comparison with the observed optical obscuration recorded at Japal-Rangpur observatory is given in this paper.

2. DATA AND METHOD OF ANALYSIS

The basic parameters monitored on a continuous basis using Satellite Radio Receiving System are (i) the amplitude and (ii) the Faraday rotation angle, Ω, of the satellite radio signals. The amplitude is used to study the ionospheric scintillations and the Faraday rotation angle, Ω, can be converted to electron content $\int Ndh$ by using the formula:

$$\Omega \text{ (deg)} = \frac{1.699}{f^2} \, \overline{M} \int Ndh \quad \ldots\ldots\ldots\ldots \quad (1)$$

where f is the frequency in Hz and $\overline{M}$ is the mean magnetic field factor in ampere-turns per metre. The accuracy of electron content values depends on the choice of $\overline{M}$ and the accuracy in the estimation of the value of Ω.

Titheridge (1972) has shown that a value of 420 km for the mean field height h_M at which the $\overline{M}$ should be evaluated is adequate in most of the cases. He has further shown that for a geostationary satellite, the value of electron content evaluated by Faraday rotation technique does not represent the integrated content upto satellite height, but only upto an intermediate height h_F which in case of Hyderabad (17.3°N; 78.5° E) is about 1800 km.

The absolute determination of the inonospheric electron content (IEC) requires the knowledge of

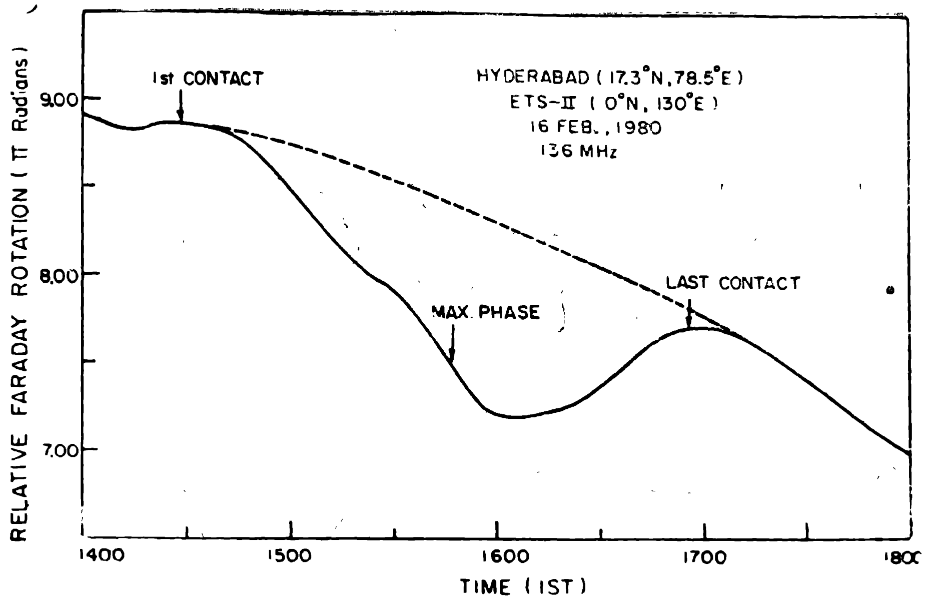

Fig. 1 : The variation of relative Faraday rotation angle during solar eclipse.

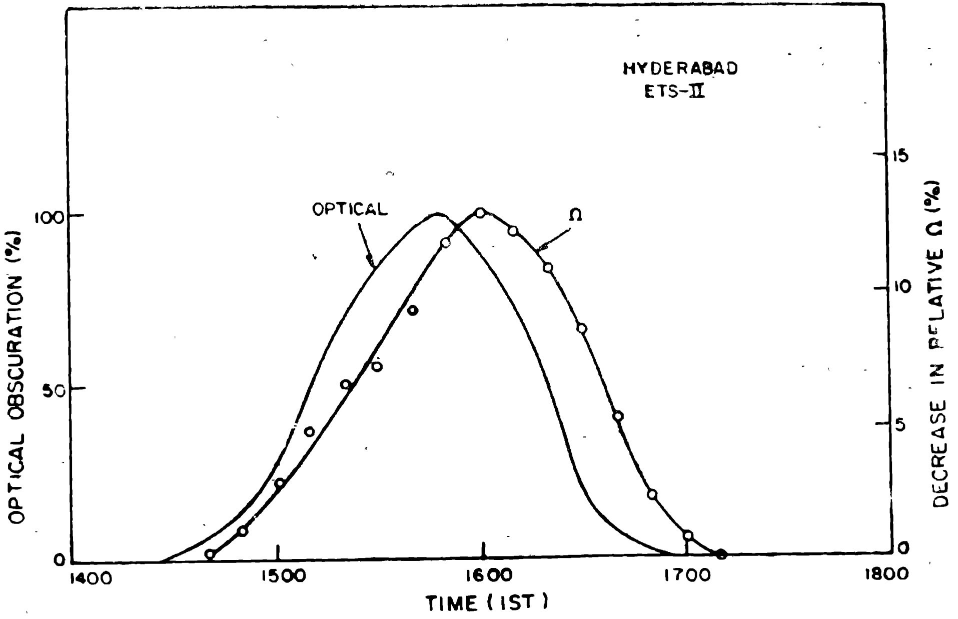

Fig. 2 : Percentage decrease in relative Faraday rotation and increase in optical obscuration of the solar disc during the total solar eclipse of Feb. 16, 1980.

TABLE 1

Station	Time (IST) of 1st Contact		Max. Phase		Last Contact		Magnitude Max. Phase
	h	m	h	m	h	m	
Hyderabad Nizamiah Observatory ..	14	28	15	47	16	56	0.99
Japal-Rangpur Observatory ..	14	29	15	47	16	56	1.04

total rotation angle, Ω, which includes the initial polarisation angle at which the wave enters the ionosphere and the integer number of half rotations experienced by the polarisation plane in traversing the ionosphere (Tyagi et al. 1977). However, for the purpose of discussing the changes during the solar eclipse, the relative Faraday rotation angle, i. e., the change in Ω from its diurnal minimum value would suffice. The variation of relative Ω, recorded at Hyderabad for the period 1400-1800 hours on the eclipse day is shown in Fig. 1. The times of the 1st contact, maximum phase and the last contact for the eclipse are marked with the arrows.

3. RESULTS AND DISCUSSION

To study the nature of changes in ionospheric electron content due to solar eclipse, the variation in Ω expected, had there been no eclipse, is represented by the dotted line in Fig. 1. Note that the electron content starts decreasing with a time lag of a few minutes from the time of 1st contact. The percentage decrease in Ω as a function of time is derived using Fig. 1 and is plotted in Fig. 2. The percentage increase in optical obscuration of the solar disc as measured by the Japal-Rangpur Observatory, Osmania University is also plotted in Fig. 2 for comparison. The curve is normalized so that the peaks in both the cases appear of the same magnitude. The resemblance between the two curves is excellent, though the changes in Ω occur with a time lag of about 12 minutes around the maximum change. The correlation coefficient between these two parameters is found to be 0.83 when no time lag is considered and 0.99 with a time lag of 10 minutes. Both the values are found to be significant at 99% level.

Chimonas and Hines (1970) and Chimonas (1970) developed a theory of eclipse induced gravity wave generation based on localized cooling near the peak of ozone absorption of solar X-ray and UV radiation at about 45 km altitude. It was suggested that as the Moon's shadow can move at supersonic speed across the ionosphere, the gravity waves would propagate in the form of a bow-wave in the wake of the shadow region. The question whether or not atmospheric gravity waves are generated in this situation is important not only in terms of the production mechanism for the waves themselves, but also, and perhaps more importantly, in terms of currently accepted models of atmospheric heating by solar radiation.

but no conclusive evidence was available in most of the cases. Schödel, et al. (1973) reported null results both in ionospheric and microbarographic observations. Hunter et al. (1975) were unable to detect any ionospheric effect close to totality. Bertin et al. (1977) observed a wave of 18 min. period but drew no firm conclusion concerning the source of observed fluctuations. Vaidyanathan et al. (1978) reported quasi-periodic fluctuations both in modulation phase delay and Faraday rotation angle recorded from ATS-6 transmissions at Trivandrum during the partial solar eclipse of April 29, 1976.

From the present recordings it is noted that apparently no Travelling Ionospheric Disturbances (TID's) were triggered by the eclipse contrary to the idea developed by Chimonas and Hines (1970). The Faraday rotation data, sampled at $2^1/_2$ minutes interval, was processed through a numerical high pass filter with a cut-off frequency of 0.11 milli Hertz (150 minutes periodicity). It was found that though a TID wave with a periodicity of $2\,^1/_2$ hours was present for several hours starting about $1\,^1/_2$ hours before the first contact and continuing for some time even after the last contact, no other TID or quasiperiodic undulations were found to be superimposed over this TID wave during the eclipse period. It is, therefore, concluded that no TID's were generated by the solar eclipse.

Note also that no scintillations were observed on the night of the eclipse day on satellite beacon amplitude recorded at Hyderabad, though strong scintillations were recorded on adjacent days. Rao (1966) has shown that the spread-F and scintillations can occur if the F-2 layer is raised to a sufficiently high altitude and then starts coming downwards. The electron drift velocity measurements show that such a reversal takes place around and just after sunset and thus gives rise to scintillations in the late evening hours (Balsley and Woodman 1971; Balsley 1977). The absence of scintillations on the night of eclipse, therefore, means that either the drift reversal is completely inhibited or shifted in time by the premature collapsing of the electrojet due to the eclipse and thus inhibiting the scintillations. The data on actual wind-measurements and the ionograms on the eclipse day should be critically examined to confirm this idea.

Experiments attempting to detect gravity waves associated with solar eclipse have met with varying degree of success. Several experiments were carried out during the eclipse of 7 March 1970 when the path of totality traversed through North America and 30 June 1973 when it traversed through West Africa. Davis and Da Rosa (1970) found perturbations in the polarization of transmissions from geostationary satellites with a quasi-period of 20 min.; Arendt (1972) observed a travelling ionospheric disturbance (TID) of 18 ± 3 min. in IEC data. Sears (1972) reported a TID of 25 min. period in phase and group path. Butcher (1973) found waves of 18 min. in phase-height measurements. These TID's in many cases were attributed to eclipse

ACKNOWLEDGEMENTS

This work forms part of a collaborative programme between the National Physical Laboratory, New Delhi & the Centre of Advanced Study in Astronomy, Osmania University, Hyderabad. The authors wish to thank the Director, N. P. L. and the Director, Centre of Advanced Study in Astronomy for making this collaborative programme a success.

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