Phase and field Measurements at VLF, LF and HF During the Solar Eclipse of February 16,1980--Preliminary Results

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Abstract

Phase and field measurements at 16 kHz (VLF) by monitoring GBR (Rugby, England) and at 10 MHz (HF) ATA (New Delhi) were carried out from Satellite Tracking and Ranging Station (Kavalur) during the solar eclipse of February 16, 1980. In addition, the field strength measurements at 164 kHz, using transmissions from Radio Tashkent, were recorded at Ahmedabad. This paper gives the preliminary results obtained from the data analyzed so far.

1. INTRODUCTION

Low frequency (LF) and very low frequency (VLF) transmissions are far more stable than high frequency (HF) since the ionosphere acts as a boundary rather than as a reflector and its variations have less influence on its stability. The phase velocity and the field strength of long range VLF and HF signals depend to an extent upon the effective height of the ionosphere and its characteristics at the time of reception. Other changes in the VLF propagation are believed to be related to polar cap events, magnetic activity, solar flare, sunspot activity, meteor showers and nuclear explosions (Beynon 1965; Wait 1963).

The effect on VLF frequencies over short (upto about 600 km) and long (upto 11000 km) paths have been studied in some detail during total and partial eclipses between 1949 and 1965 (Bracewell 1952; Craryar et al. 1965; Albee et al. 1965).

The aim of our experiment was to study the effect of the solar eclipse in VLF and HF region at medium path lengths from 1700 km to about 8000 km by monitoring frequency and time signals transmitted by distant stations.

The phase and field strength measurements were carried out from Kavalur (12°34′N, 78°49′E) at 16 kHz by monitoring GBR (52°22′N, 01° 11′W) and at 10 MHz by monitoring ATA (28° 34′ N, 77° 19′E) during the solar eclipse of February 16, 1980. Field stregth measurements were recorded at 164 kHz at Ahmedabad using Radio Tashkent transmission.

2. INSTRUMENTATION, CALIBRATION AND METHODS OF OBSERVATIONS

VLF 16 kHz signal; transmitted by GBR (Rugby) were received at Kavalur using a loop antenna oriented to receive maximum signal level. The local crystal oscillator (HP 105 B), having a stability of the order of 1 part in 10^{11}, was phase locked to the signal received from GBR. The criteria used for selecting the signal from GBR were the relative uncertainity of only 2 parts in 10^{12} of the carrier frequency and the high signal to noise ratio. The local oscillator, the VLF receiver and the data recorder were run on battery supply through out the experiment. The phase measurements were carried out seven days before eclipse and seven days after the eclipse as well. The data were recorded on a pressure sensitive strip-chart recorder.

The VLF receiver was Datum Inc., model 9880 A, which is tunable between 10 kHz and 30 kHz in steps of 100 Hz. The image rejection is 50 dB or better. Overall gain of the system is 85 dB at 16 kHz. This unit provides the means for developing precise information about the change in the phase relationship between received VLF transmission and a local reference frequency source. The information provides the criteria for making appropriate adjustments to the local reference source so as to improve its accuracy.

The local oscillator was calibrated using VLF receiver so that the frequency of the oscillator was precisely tuned to the received signal. The phase matching accuracy was of the order of one microsecond, which is the limit of the resolution of the strip-chart recorder. VLF signal was tracked at the tracking rate of 0.2 microsecond per second.

The Hf signal at 10 MHz was monitored using transmissions from ATA (New Delhi). ATA transmissions were switched on round the clock between February 14-18, 1980 on 5 MHz, 10 MHz and 15 MHz frequencies at the output power of about 8 kW. The received signals at 5 MHz and 15 MHz were found to be very noisy with very low signal to noise ratio between February 14-18 and therefore data at these frequencies were not found useful. ATA transmits second pulses of 1 kHz modulation and with pulses of 100 milliseconds duration every minute in UTC system. The receiver used was USSR made allwave continuously tunable (10 kHz to 30 Mhz) receiver (VOLNA -K) and a highly stable crystal oscillator (with a stability lx 10^{10}/°C) and a built in phase shifter. During the eclipse, measurements were made at every five minute interval on a Tektronix storage oscilloscope (No. 466) having 100 MHz bandwidth.

3. RESULTS

3.1. VLF (16 kHz)

In Figure 1 (a) is given the variations in the mean phase averaged over seven control days at every 15 minutes interval. Figure 1 (b) gives the observed phase anomaly with the time scaled at every 2.5 minutes during the eclipse.

Figure 1 (a) shows that during normal days, mean phase of the recorded signal is almost constant between 1300 hours and 1530 hours and increases gradually after 1545 hours to a constant value at night time.

At the start of the eclipse, the phase was observed to decrease by about 6°, though this was not expected, and then there was a gradual increase in phase. Similar decrease in phase has also been reported in the literature (Albee et al. 1965). The maximum phase anomaly was observed at the eclipse maximum, which was of the order of 34.5$\pm$3°. This may be due to the fact that the D region concentration gradual- due to the fact that the D region concentration gradually decreases and tends to disappear as the Sun is gradually obscured by the Moon. As the D region ionisation decreased, the VLF reflection height increased, causing an increase in the observed VLF phase. After the eclipse maximum, the phase decreased as expected until about 1545 hrs. No complete symmetry was observed in the phase variations with epoch during the eclipse and this may be due to the effect of the sunset on the D region interfering with eclipse effect on VLF signals. After the end of the eclipse, variation in the phase of the VLF signals with time was as observed during the normal days.

3.2 HF (10 MHz)

In Figure 2 is plotted the variation of the amplitude of 10 MHz signal measured during the eclipse and one day around it during the same time. The amplitude of the signal at 10 MHz was observed to increase during the eclipse period and there was a gradual fall in the amplitude as the eclipse reached its minimum. After the eclipse the variation in amplitude of 10 MHz ATA signal was observed to be normal as any other day. Similar results are reported using different techniques (Lerftas et al. 1963).

3.3. LF (164 kHz)

The field strength measurements were also made at Ahmedabad on a few days before and after the eclipse. The variations of the relative field strength on a control day (February 17) and on eclipse day are shown in Figure 3. On the eclipse day, an increase is noted in the field strength from about 1400 hours. The maximum field strength is noted around 1600 hours, which is little after the time of total eclipse.

These results at VLF, LF and HF range are consistent with the eclipse time decrease in the ionization resulting in the decreased absorption in Dregion and increase in the VLF reflection height as evidenced by the increase in phase associated with the eclipse.

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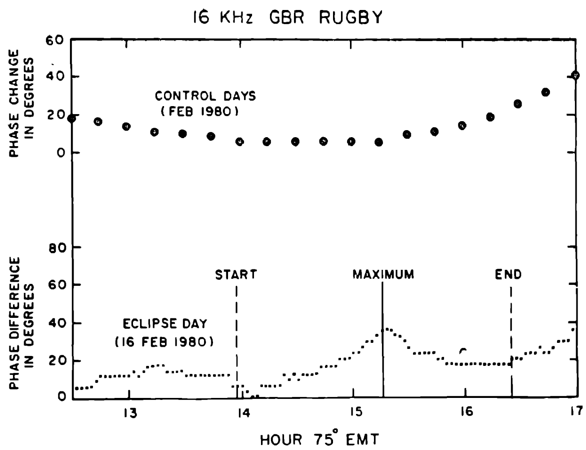

Fig. 1: The variations in (a) mean phase averaged over seven control days and (b) phase on eclipse day of the VLF 16 kHz transmission recorded at Kavalur.

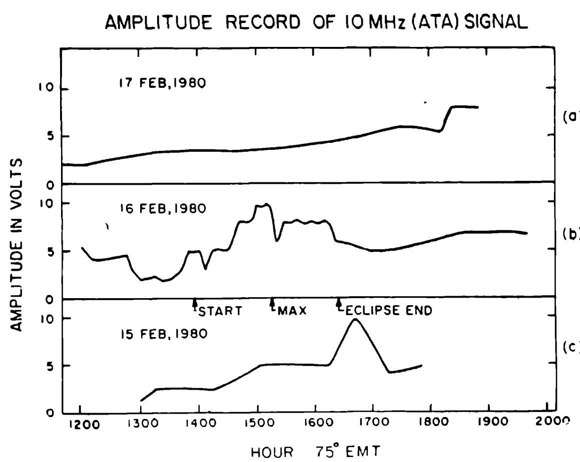

Fig. 2: The variations in amplitude at 10 MHz signal measured at Kavalur during the eclipse day and on a day around it.

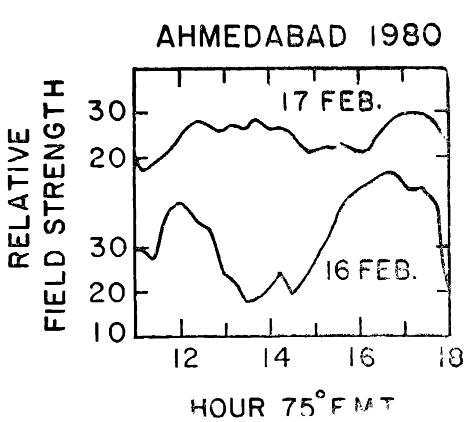

Fig. 3: Field strength measurements at 16 kHz using Radio Tashkent, recorded at Ahmedabad for February 16 and 17, 1980.