VLF observation of a Solar Flare by Lunar occultation during annular solar eclipse of January 15th, 2010

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Abstract

We report the results of our monitoring of the NWC transmitter from Khukurdaha ($\sim$ 80 km away from Kolkata) during the partial solar eclipse (75%) of 15th January, 2010. The receiving station and the transmitter were on two opposite sides of the annular eclipse belt. We got clear depression in the data during the period of partial eclipse. However, most extraordinarily, there was a solar flare (spot no. 1040) on that day during the time when the eclipse was near maximum. The flare started from B type, reaching maximum to C1.3 (as observed by GOES 14 satellite). We saw the occultation of this flare by the moon's limb. To our knowledge this is the first such incident where the solar flare was observed through lunar occultation.

1 Introduction

Solar eclipses are unique to study the behavior of the VLF signals under controlled experimental condition since the time and space of the event is known well ahead of time. Several observers have reported VLF observations during eclipse [1-4]. However, it is very rare that a solar flare would be blocked by the moon's limb. We report here the results of this extra-ordinary event.

When a solar flare occurs, the extra ionization generated by the X-rays lowers the effective reflection height of the ionosphere by an amount that depends on the intensity of the X-ray flux [1]. On 15 January 2010, an annular solar eclipse occurred but the eclipse was partial from Khukurdaha (22°27′N, 87°45′W), our receiving site (R). The zone of annularity swept across the Indian ocean and the central path continues into Asia through India (Fig.1) at around local midday. At the receiving station, the maximum coverage of the solar disk was 75% (see, Table.1). As the eclipse progressed and the signal started diminishing, a solar flare (C1.3) occurred and had a maximum just after the maximum obscuration, thus enhancing the signal abruptly. The signal subsequently continued to rise as the eclipse was ending.

In the present work we examine the effects of solar eclipse of January 15, 2010 on the NWC (19.8 kHz) VLF signals. The receiving station and transmitting station are in opposite sides of the annular solar eclipse zone (AB, Fig.1). The effect was further complicated due to the occurrences of a solar flare (C1.3) as recorded by GOES 14 satellite (in two energy bands: 1.5 keV to 12.0 keV and 3 to 25 keV) when the moon was blocking the sun.

Table 1: Details of partial eclipse at Khukurdaha [5]

Receiver lat, long	Eclipse coverage %	1st contact(IST) Altitude (deg)	Mid contact(IST) Altitude (deg)	2nd contact(IST) Altitude (deg)
Khukurdaha 22°27′N , 87°45′E	Partial 75.1	12:05:30 +46	13:56:26 +36	15:28:28 +27

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2 A Flare during Eclipse

The annular solar eclipse of January 15, 2010 started at 12:05 IST and continued up to 15:28 IST, which was visible partially (maximum coverage 75%) from Khukurdaha. The mid contact was at 13:56:26 IST. The Table 1, also shows the altitude of the sun (degrees) at these three contact points. Since the transmitter was far away from the eclipse belt, on the way from NWC to Khukurdaha the 1st, 2nd and 3rd hop points went through an eclipse coverages of (23%, 63%, 78%) respectively as measured 70 km above the ground. The C1.3 solar flare started at 07:22 UT (12:52 IST) and continued till 10:22 UT (15:52 IST) with a maximum at 08:41 UT (14:11 IST). Thus the flare peak was only 15 minutes after the maximum obscuration by the eclipse. The peak energy flux in 1.5 keV to 12 keV was 8.9×10^{-3} ergs/cm^{-2} which is well above the detectability of our VLF antenna (typically B8 flare). GOES Satellite was observing the sun in an unobstructed manner, so it saw the whole flare. In Fig. 2, we superposed the magnetogram data of the sun on the solar disk occulted by the moon at the time of maximum obscuration. Clearly we note from visual inspection that a part of the active region (No. 1040) is blocked by the moon.

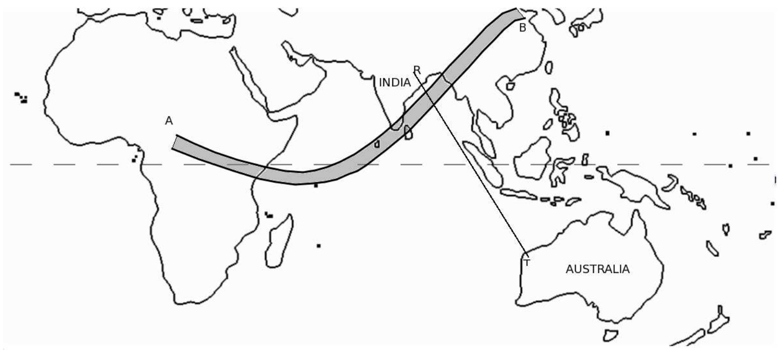

Figure 1: The propagation path of 18.2 kHz from NWC to Khukurdaha is shown by TR. The shaded area from A to B is the path of total annularity of January 15, 2010 [5].

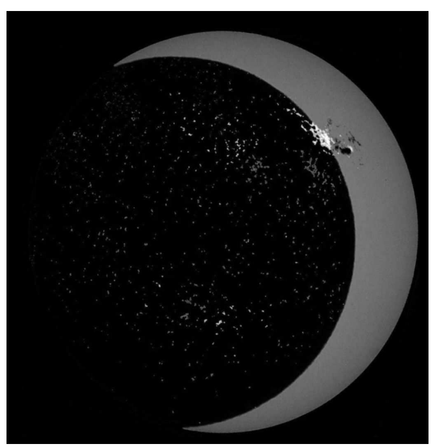

Figure 2: Magnetogram superposed on the visual Sun [5].

3 The Experimental Setup, Methodology and Results

A loop antenna and Gyrator III type receiver were deployed to monitor VLF data at Khukurdaha. Real time narrow band amplitude data from several transmitter is being recorded automatically in the computer. Detection of a weak flare in NWC data is a very routine activity from our receiver. So in the 15th January data, any ‘dissimilarity’ with GOES flare shape can be attributed to the blocking of the active region by the lunar disk.

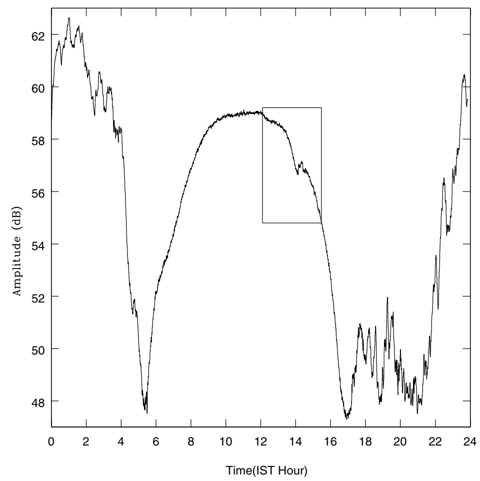

Figure 3: 24 hour data from our receiving station on the eclipse day. The box highlights the ionospheric disturbances observed due to the eclipse and the flare. Data is normalized by LWPC midday value with respect to our receiving station [5].

In Fig. 3, we present the amplitude (in dB) variation of the NWC signal as obtained by our receiver on the 15th January. The box highlights the region around the eclipse which clearly shows a dip near the eclipse maximum and a upward kink near the flare maximum. For the analysis of the effect of the eclipse we consider the data of three days from 14th January to 16th January, 2010. We normalized the data with the amplitudes in the midday and midnight as predicted by Long Wave Propagation Capability (LWPC) code [6]. The data of the three days are plotted in Fig. 4. The data of the 14th and the 16th are clearly smoother as compared to that on the 15th. We now proceed to obtain the effect of the eclipse and the flare systematically in the following way.

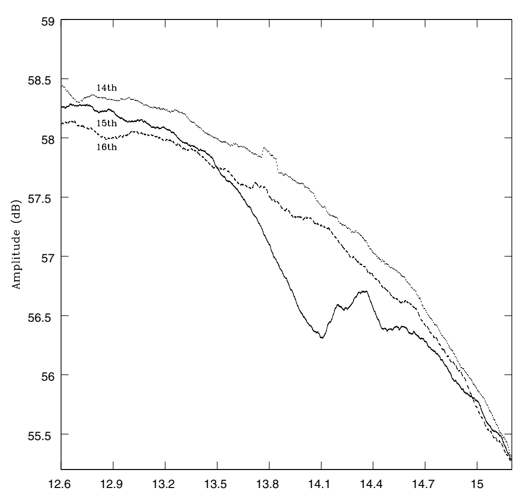

Figure 4: Comparison of VLF data with the data of the 15th January 2010, with that of the 14th and the 16th [5].

Our main result indicates that the VLF signal was not minimum when the sun was at maximum obscuration. The difference is almost 5 minutes. Similarly the peak of the flare observed is also about 8 minutes after the actual solar peak. Both are too big to be due to ionospheric recombination effects. Our result must be due a combination of the eclipse and the flare effects. The detailed analysis is in progress and the results will be reported elsewhere.

4 Acknowledgments

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