# VLF observational results of total eclipse of 22nd July, 2009 by ICSP team

***Sandip K. Chakrabarti***[2,1], ***S. Pal***[1], ***S. Sasmal***[2], ***S. K. Mondal***[2], ***S. Ray***[2], ***T. Basak***[1], and ***S. Maji***[2]

[1] S. N. Bose National Centre for Basic Sciences, Block-JD, Sector-II, Salt Lake, Kolkata-700098, India, chakraba@bose.res.in, sujay@bose.res.in, tamalbasak@bose.res.in

[2] Indian Centre for Space Physics, 43 Chalantika, Garia Station Road, Kolkata-700083, India, sudipta@csp.res.in, sushanta@csp.res.in, suman@csp.res.in, surya@csp.res.in

## Abstract

Solar eclipses provide us with exciting opportunity to study the VLF propagation effects under a controlled experiment in a cosmic scale. During the total eclipse of July 22nd, 2009, we conducted a campaign to obtain the data from more than a dozen places. We observe that in several places the signal amplitude is amplified, while in other places the amplitude is reduced. In yet other places, there are ups and downs in the signal during the obscuration period. In this paper, we present the results of our campaign during the total solar eclipse.

## 1 Introduction

During total solar eclipses, the UV and soft X-ray photons from the solar disk is blocked for certain time interval and the precise time of this event is known well ahead. This makes these events ideal candidates to study the global variation of ion concentration in the ionosphere which could be useful for ion chemistry. Keeping this in mind, Indian Centre for Space Physics conducted a campaign in which data from more than a dozen places were collected. Preliminary results are presented in Chakrabarti et al [1-2].

## 2 Campaign During Eclipse

During the Total solar eclipse on 22nd of July, 2009, the VLF group undertook a major campaign in which 12 stations were covered. We typically took data of about a week around the eclipse in order to study the deviation from the normal day very accurately. Table 1 shows the parameters of and at the receiving stations. We show the locations with latitude and longitude, the percentage of eclipse coverage, the time of the first contact, the maximum eclipse time, the last contact and the altitude (A) of the sun (with respect to the local horizon) in degrees at those times. In Fig. 1, we present the path of totality along with the names of our stations vis-á-vis the VTX transmitter in the southern tip. The locations of the stations are also marked with English alphabets A-K. During the campaign, signals from VTX and NWC stations were picked up. Since NWC and VTX are on the same side of the eclipse path (namely, south) the propagation paths cross the eclipse paths in the same way, although a part of the propagation path to NWC was out of eclipse zone.

As an example of the data received by our stations we show in Fig. 1 the 'raw' signals for a whole week of data around the eclipse time as observed from our Salt-lake (Kolkata) station. The dates are marked on each curve. The time is given in seconds starting after midnight of Indian Standard Time (IST=UT+5:30). The data of each day is shifted vertically by 5 dB to see them clearly. The arrow on the 22/7 data indicates the time of maximum obscuration of the sun as seen at Salt-Lake (see Table 1). The bump around the arrow is a clear indication of enhanced signal amplitude during the eclipse.

Altogether, we observe three types of VTX amplitude variations. In Figs. 3(a-b), we show two types. In all the cases, we present the fractional change in signal amplitude $A_f$ which is measured by subtracting average amplitude of VTX signal from the amplitude of the eclipse day. In Fig. 3a, we show the results of

978-1-4244-6051-9/11/$26.00 

Table 1: Total solar eclipse parameters at different receiving stations (Chakrabarti et al. 2010).

| Place & Geographic lat,long | Coverage % | Sunrise | 1st | Mid | 2nd |
|---|---|---|---|---|---|
| Coochbehar 26°19N, 89°28'E | Total 100 | 04:53 | 05:30:16 A(7.1) | 06:28:43 A(19.6) | 07:34:06 A(34) |
| Salt-Lake 22°34N, 88°24'E | Partial 89.9 | 05:04 | 05:28:46 A(05) | 06:26:20 A(17) | 07:30:54 A(32) |
| Malda 25°N , 88°09'E | Partial 99.6 | 05:00 | 05:29:34 A(05) | 06:27:24 A(18) | 07:32:04 A(32) |
| Raiganj 25°36'N , 88°08'E | Total 100 | 04:59 | 05:29:52.3 A(5.6) | 06:27:43.1 A(18.1) | 07:32:22 A(32.4) |
| Khukurdaha 22°27'N , 87°45'E | Partial 90.7 | 05:07 | 05:28:43.8 A(04) | 06:26:3.0 A(17) | 07:30:16.9 A(31) |
| Bhagalpur 25°15'N , 87°01'E | Total 100 | 05:04 | 05:29:41 A(05) | 06:27:02 A(17) | 07:31:04 A(31) |
| Kathmandu 27°45'N , 88°23'E | Partial 96.3 | 05:21 | 05:31:10 A(04) | 06:27:43 A(16) | 07:30:30 A(30) |
| Benaras 25°22'N , 83°E | Total 100 | 05:20 | 05:30:04 A(01) | 06:25:44 A(13) | 07:27:33 A(27) |
| Kangra 32°58'N , 76°16'E | Partial 65.3 | 05:32 | 05:37:19.7 A(00) | 06:28:45.3 A(10.1) | 07:24:46.1 A(21.6) |
| Jaipur 26°55'N , 75°52'E | Partial 87.6 | 05:46 | 05:32:53 A(-03) | 06:25:32 A(07) | 07:23:18 A(20) |
| Kashmir 34°08'N , 74°51'E | Partial 59.4 | 05:35 | 05:40:12 A(00) | 06:30:04 A(10) | 07:24:04 A(21) |
| Pune 18°31'N , 75°55'E | Partial 93.2 | 06:08 | 05:30:00 A(-09) | 06:21:54 A(02) | 07:19:03 A(15) |

the stations B, E and I where $A_f$ is large and positive with a peak near or at the eclipse maximum. The time along X-axis is in Indian Standard Time (IST=UT+05:30 hr.). Note that more than twenty percent variation was found to be typical. In Fig. 3b, we show the results of the stations C, D, G where $A_f$ is large and negative with a trough at the eclipse maximum. Here too the change could be more than twenty percent. In the third type of variations in other places, we find many ups and downs and even changes as large as 60% could be seen. Our results indicate that there is little correlation between the local coverage and $A_f$ and the result may be reproduced only using detailed calculations of interferences among the sky wave and the ground waves along the propagation path.

NWC signal, on the other hand, showed more intricate shape generally because a part of the part was totally out of the eclipse path, while a fraction of the path was exposed to only partial eclipse. In Fig. 3 (c-d), we show some of these results. In Fig. 3c, the signals show high negative changes at stations B, E and G. In Fig. 3d, the fractional changes show many ups and downs at stations C, D, H and K.

On the whole, we have very good data from about a dozen stations during the eclipse. The full analysis has not been completed yet. But already it appears to be interesting: It is not very straightforward to say whether the signal would be enhanced or reduced at a given place. The final result at any given location appears to be strongly dependent on exactly how the propagation path is disturbed during an eclipse.

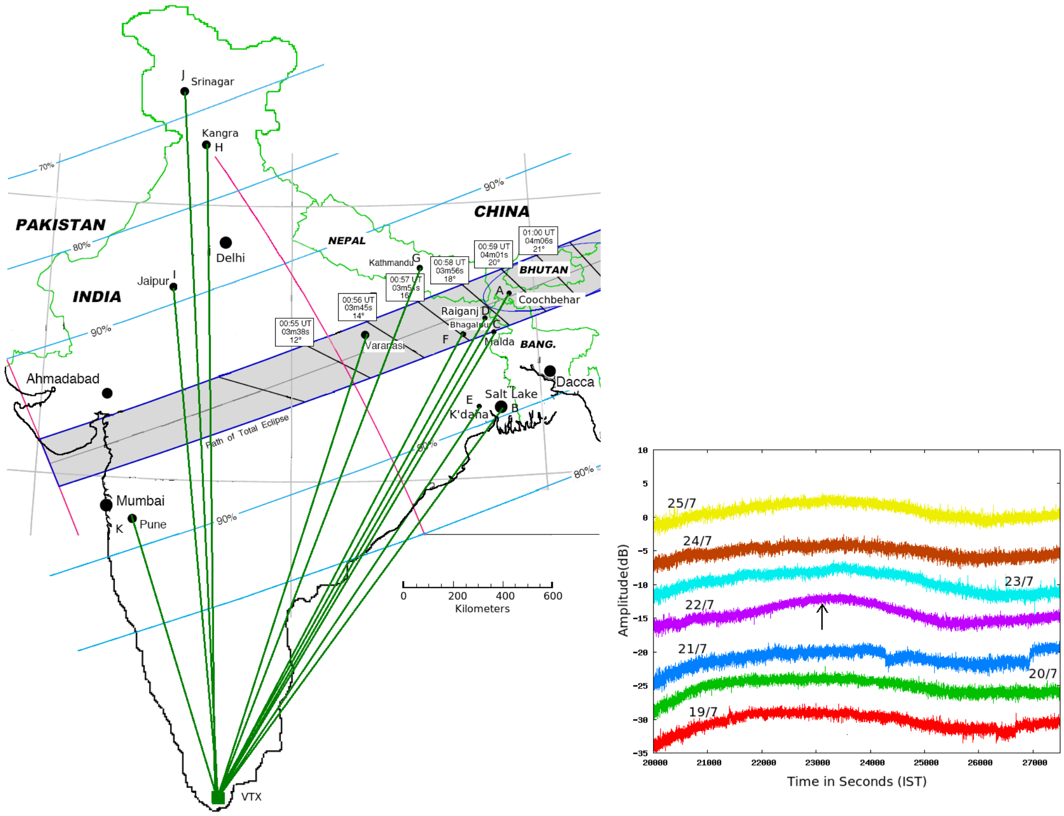


Figure 1: (a) Left: The path of totality over Indian subcontinent during the total solar eclipse on 22nd July, 2009. Our receivers and the VTX station are marked. This Figure is modified from that provided by F. Espenak & J. Anderson in NASA 2009 Eclipse Bulletin to include our campaign locations. (b) Right: An example of raw data obtained at Salt Lake during 19th July, 2009 to 25th July, 2009. The signal amplitude of each day has been shifted by 5 dB vertically to see them clearly. The time is in seconds after midnight (IST). The time of maximum of the eclipse is shown with an arrow on 22/7 data [1].

## 3 Discussions

There are several papers in the literature which reported results of VLF signals during eclipse. However, there was no concerted effort to tabulate the results in a short distance propagation. ICSP lead campaign provides, for the first time, the effects of total and partial eclipse over short range propagation. We find that in some regions, the signal is enhanced while in some other regions, the signal is reduced. We believe that the result is due to propagation effects. During the eclipse, the ionospheric height is modified differently at different regions and the interference pattern between the sky wave and the ground wave could become constructive to destructive and vice verse, depending on the path length. In the mode theory also, since the eclipse change the shape of the wave guide differently the signal obtained by the sum of the modes would be different along different propagation path. These aspects will be models using both the wave-guide theory and the wave-hop theory and the results would be presented elsewhere.

## 4 Acknowledgments

The work of S. Pal, S. K. Mondal, T. Basak is supported by CSIR fellowships and the work of S. Sasmal is supported in part by an ISRO/RESPOND project. The authors are thankful to many team members of the campaign, namely, A.K. Choudhury, K. Giri, B. Khadka, N. Iqbal for helping procuring the data.

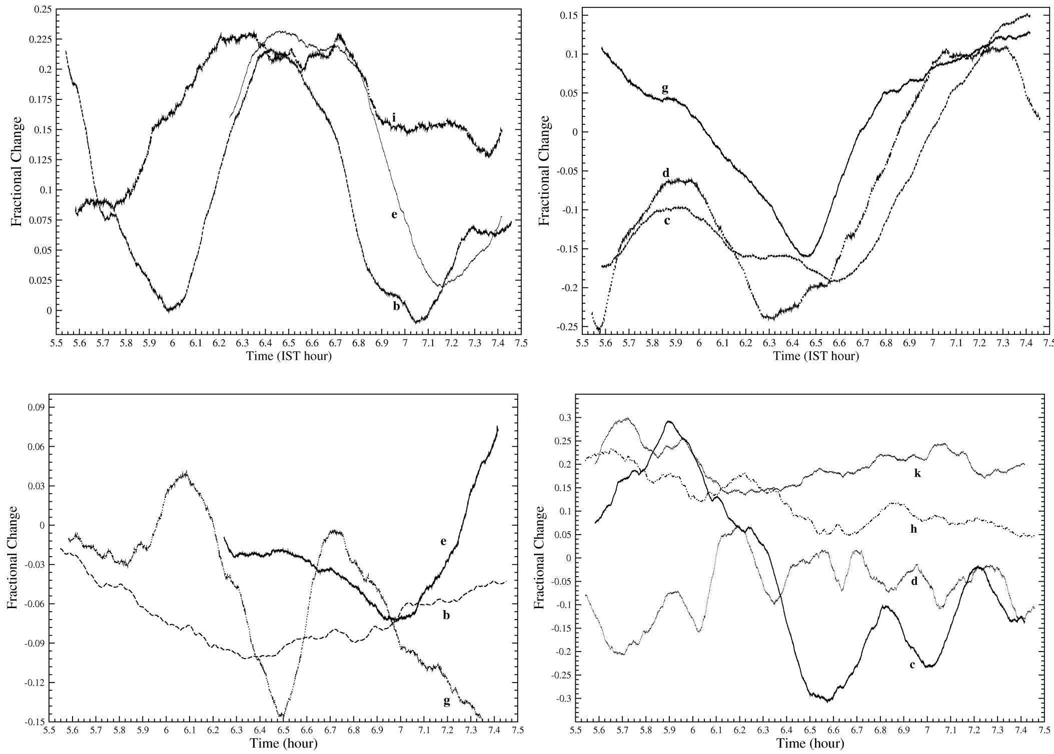


Figure 2: **(a-b):** Fractional change variations of VTX signals observed during the total solar eclipse on 22nd July, 2010. The fractional change of signal amplitude $A_f$ is plotted against the Indian Standard Time around the eclipse (maximum is around 06:30 IST; see Table 1). We note that $A_f$ at the eclipse maximum could be large (a) positive and (b) negative. At other places, the variation pattern is more complex. **(c-d):** Two types of NWC signals fractional change variations were observed during the total solar eclipse on 22nd July, 2010. The fractional change of signal amplitude $A_f$ is plotted against the Indian Standard Time around the eclipse (maximum around 06:30 IST; see Table 3). We note that $A_f$ at the eclipse maximum could be basically (c) negative or (d) of strange shape changing signs [1].

## 5 References


1. S.K. Chakrabarti, S. Sasmal, S. Pal, S.K. Mondal, "Results of VLF Campaigns in Summer, Winter and during Solar Eclipse in Indian Subcontinent and beyond", in *Propagation Effects of Very Low Frequency Radio Waves, Ed. (S. K. Chakrabarti), AIP Conf. Proc.*, 2010, vol-1286 (AIP, New York).

2. S.K. Chakrabarti, S. K. Mondal, S. Sasmal, S. Pal, T. Basak, S. Chakrabarti et al., "VLF signals in summer and winter in the Indian sub-continent using multi-station campaigns", *Ann. Geophys.*, 2011, (submitted).