Modeling VLF signal amplitudes over Indian sub-continent during the total solar eclipse

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Abstract

We present the simulation results incorporating the effect of solar eclipse (22nd July, 2009) on VLF signals for West-East propagation path with respect to Indian Navy transmitter (VTX) assuming a Gaussian variation of the ionospheric reflection height as a function of propagation distance along the transmitter-receiver great circle path. We use both the wave-hop and the Long Wave Propagation Capability (LWPC) codes. Using wave-hop theory we found that a reasonable matching between the observed and simulated results are achieved.

1 Introduction

It is well known that solar eclipse perturbs the ionosphere. As a result, the propagation of VLF/LF waves are affected and provide us a unique opportunity to study the behaviour of the ionosphere under a controlled experiment of cosmic scale. The propagation mechanism of these waves can be well understood in terms of waveguide mode theory or in some circumstances by ray theory (wave-hop). Generally waveguide mode theory, namely Long Wave Propagation Capability (LWPC) model is used [1] to understand the ionospheric behaviour and explain the features in the observed VLF/LF pattern [2].

Chakrabarti et al. [3-4] found both positive and negative fractional changes in VLF amplitudes roughly in the same propagation direction from the VTX transmitter during the total solar eclipse 22 July, 2009. To reproduce the observed features here we use both wave-hop and LWPCv21 programs.

2 Propagation path and the results

Here we mainly study the behaviour of the VLF signal transmitted from VTX transmitter $8^{0}23$'N, $77^{0}45$'E at 18.2 kHz during the total solar eclipse 2009. Salt Lake and Khukurdaha were below the TSE belt with maximum coverage around 90%, while Malda was marginally on the TSE belt and Raiganj and Coochbehar were within the TSE belt. Kathmandu was above the TSE belt.

In Fig. 1, we show the amplitude variation at 6:30 AM using wave-hop code. The dashed curve represents the signal amplitude variation from VTX transmitter at normal conditions with bearing 34.6 degree. The solid curve shows the same variation during the maximum eclipse condition. Six receiving places in this direction are marked in the Figure by solid straight lines. In Fig. 2 we show the differences of the two curves. We can easily see that in some places the signals are enhanced and in some others the signals are reduced. These results match almost exactly with the observed results [3-4].

We now compare the results using the LWPCv21 code. In Fig. 3, we plot the amplitude variation along the same bearing angle.

In order to understand the nature of changes which take place over the Indian sub-continent during the eclipse, we calculate effective the height (h') and β parameters using both the codes. In Fig. 5 we show

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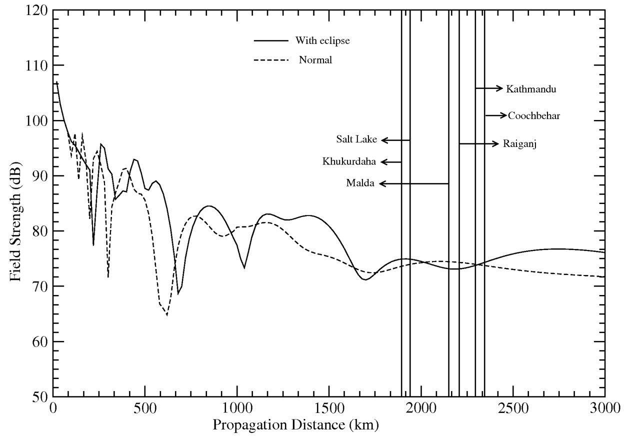

Figure 1: Amplitude variation at 6:30 AM using the wave-hop code, dashed curve being the signal amplitude variation from VTX transmitter at normal conditions with bearing at 34.6 degree. Solid curve shows the same variation during the maximum eclipse condition. The receiving places in roughly the same bearing angle are marked by solid straight lines.

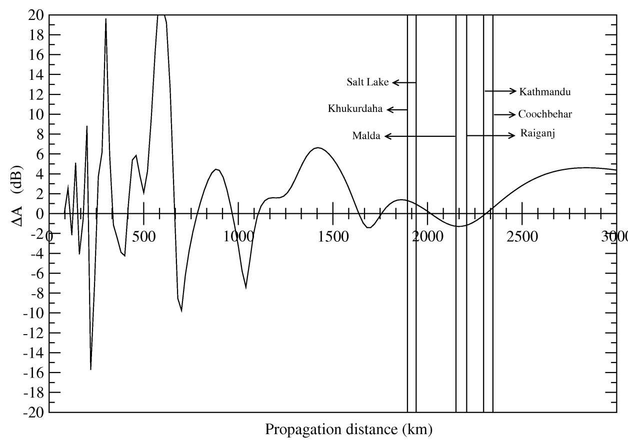

Figure 2: Differential amplitude variation between the eclipse and normal day with wave-hop code. Within distances between 1750-2000 km fractional change of amplitude is positive, within distances between 2000-2300 km fractional change is negative and beyond 2300 km fractional change is again positive. Six receiver was within this distances (1750-2400) and got exactly the same features at the time of maximum eclipse. Observed and simulated fractional changes match very well.

the results. In the upper panel, we show the variation of the effective reflection height (upper panel) with distance from the transmitter at the time of maximum eclipse. The dashed curve shows the reflection height variation used for wave-hop code for which the simulated fractional amplitude change matches with the observations at defined six places. The solid curve shows the effective reflection height (h' parameters in so-called Wait's model of exponential ionosphere) variation used for LWPC code with the same functional variation as in the wave-hop model. Lower panel shows the variation of the sharpness parameter β with distances at the same time. Total solar eclipse occurred within the region from 2100-2400 km along the propagation path.

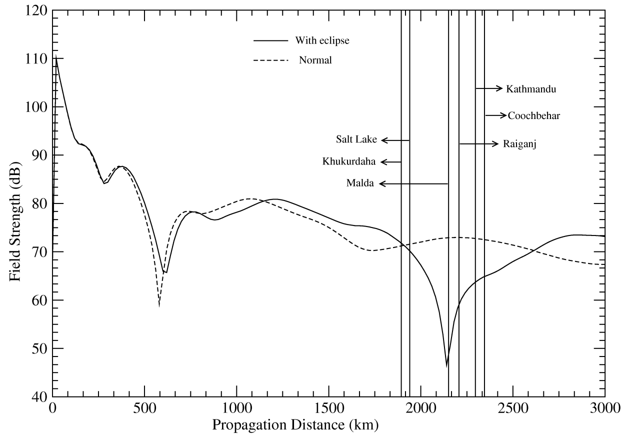

Figure 3: Same as in Fig. 1 but using the LWPCv21 code.

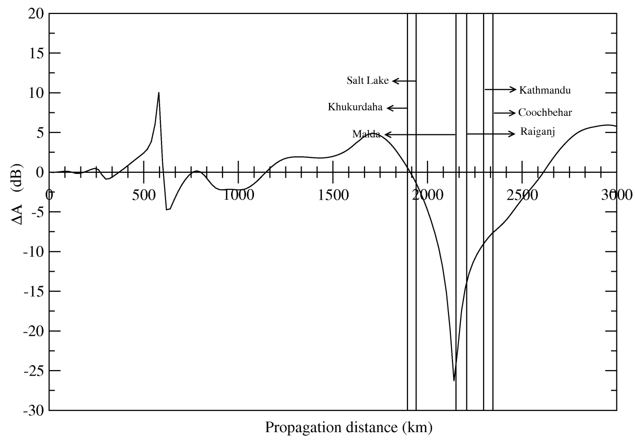

Figure 4: Same as in Fig. 2 but using LWPCv21 code. In this case, all the places between 2000-2600 km show negative fractional change in amplitude. Changes in β and h' parameters produce similar features. The result does not match with observations.

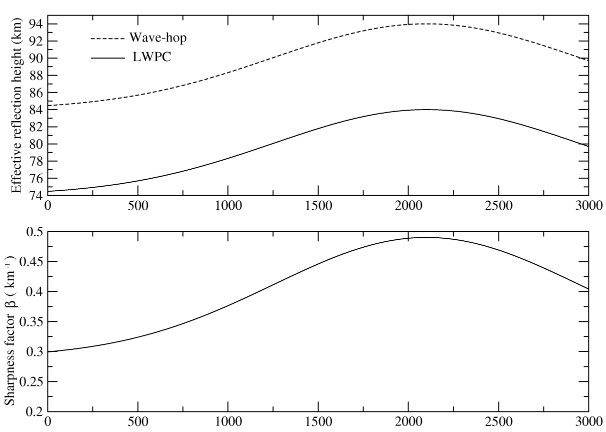

Figure 5: The variation of h' (upper panel) and the sharpness parameter β (lower panel) with distance from the transmitter at the time of eclipse maximum. Total solar eclipse occurred within the region from 2100-2400 km along the propagation path. See, text for details.

3 Conclusions

We presented the variation of the signal amplitude with distance from the transmitter during the totality. We find that the observed fractional changes in signal amplitude match with the computed results only if the wave-hop theory is used. The LWPCv21 program does not account of the positive and negative changes in the signal amplitude during eclipse. It is possible that the distances concerned are smaller compared to the distance beyond which LWPC program convergence is fast and it yields more accurate results. We are in the process of incorporating the magnetic fields so as to reproduce the east-west propagation asymmetry so that the observed results in the west of the transmitters may also be explained.

4 Acknowledgements

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5 References

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