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Combined effects of Geomagnetic storm and regional Earthquake on low latitude VLF radio signals: A case Study

Prabir Kr Haldar* (1), Bakul Das(1), Arnab Sen (2), Sujay Pal(3)
(1)Department of Physics, Cooch Behar Panchanan Barma University
Vivekananda Street, Cooch Behar, West Bengal 736101, India
(2) Department of Education in Science and Mathematics, NERIE, NCERT, Shillong, Meghalaya 793103, India
(3) Department of Atmospheric Sciences, University of Calcutta, Kolkata-700019, India
**prabirkrhaldar@gmail.com*

Abstract

Anomalous behavior of Very Low Frequency (VLF) radio signals from the VTX (18.2 kHz) and NWC (19.8 kHz) transmitters during geomagnetic storm, followed by a moderate size earthquake, are analyzed and presented in this paper. There was Geomagnetic storm on 10th and 11th September, 2018 and a moderate size isolated earthquake on 12th September, 2018. Using standard deviation method, night time VLF amplitude of both the propagation path are found to deviate beyond -3sigma level on 10th September coinciding with the occurrence of geomagnetic storm. Pre-seismic and post-seismic signal anomalies are also identified in both propagation paths linked with the earthquake of 12th september 2018.

1 Introduction

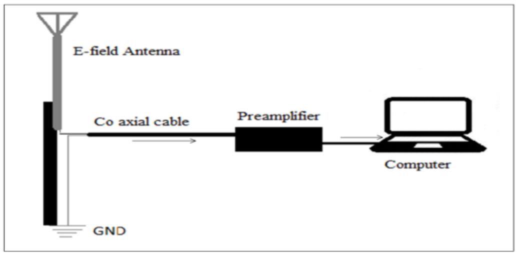
Earthquake is a combination of complex physical and chemical processes and responsible for large number of disasters. It is possibly a lithosphere-atmosphere-ionosphere coupling phenomena effecting the electromagnetic wave propagation [1]. Due to the extreme complexity of the earth's structure the goal of predicting the location and time of occurring of a seismic event has not come by [2]. Very Low Frequency Radio wave propagates through the Earth Ionosphere Wave Guide (EIWG) and carries the information of Ionospheric state. Earlier studies stated that the amplitude and phase of VLF signal, Morning and evening terminator time of a 24 hour diurnal variation and other parameters show anomalous behavior before a particular impending earthquake [3- 7].

Solar Coronal Mass Ejection or sudden variations in the Earth's magnetic field causes the geomagnetic storm which is directly connected to the occurrence of earthquake, as discussed in some previous studies [8-10]. During a geomagntic storm the Ionospheric D-region electron density changes which reflect as a fluctuation in the VLF signal amplitude [11-13]. The geomagnetic activity affects not only the high and mid latitude but it could take place in low latitude also [14]. The Kp index indicates the enhancement in the geomagnetic activity. A Kp value greater than 5 is indicates to a geomagnetic storm. A study published in 2014 correlated the occurrence of geomagnetic storm and earthquake [15].

2 The Experimantal Setup and Data for Analysis

We use an aluminum pipe as VLF antenna connected to the receiver by a 75 Ohm Co-axial cable. The negative terminal of the receiver (or sound card) is grounded using a 2m iron rod. It is mainly a two-stage amplifying system which uses two numbers of LF356 OPAMP. The output of the preamplifier system is taken out through an audio transformer (1300:8 Ohm) and fed to the Microphone input of the PC soundcard. The composite wave (ground and sky-wave) in the VLF range (3 kHz to 30 kHz) incident on the antenna generates a voltage which is then amplified by the pre amplifier section of the receiver and recorded by the sound card. The recording software (Spectrum lab V2.7b20) records the variation of amplitude of the VLF wave at a sampling rate 4/Sec as text file. The system is shown in Figure 1.

In this paper we have presented the fluctuations in the VLF signals of VTX (18.2 kHz) and NWC (19.8 kHz) during an earthquake of M5.4 triggered just after the geomagnetic storm having Kp≥6. The Earthquake (EQ) event was on 12th September, 2018 at 10:20:46 (UT+5:30) and the epicenter [26.374°N, 90.165°E] was at 7 km NE of Sapatgram, Assam, India. The epicenter was just 84 km away from the VLF receving station Cooch Behar [CHB, 26.345°N, 89.448°E] and the shaking was felt by local community at VLF receiving station. There was no earthquake event ±15 days before or after the said event, according to the information provided by United States Geological Survey website. On the other hand the geomagnetic activity of Kp=5 was started at 20:30:00 (UT+5:30) on 10th September and increased upto Kp=6 at 14:30:00 (UT+5:30) on 11th September, 2018.



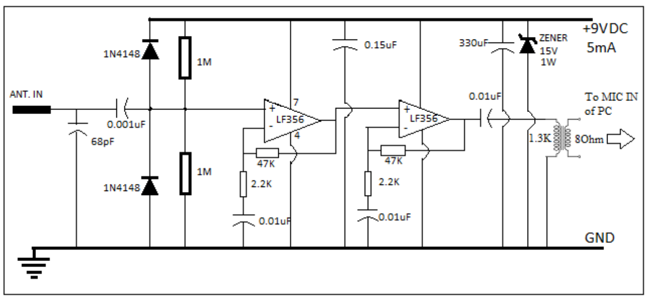


Figure 2(a). Schematic diagram of the VLF signal receiving system. Figure 2(b) Preamplifier which is used to amplify and record the VLF signal.

VLF signals transmitted from VTX station at Vijaynarayanam [8.433°N; 77.733°E] and NWC [21.816°S; 114.165°E] are received at Cooch Behar [26.334°N; 89.326°E]. The Great Circle paths (GCP) are shown in the map in Figure 2.

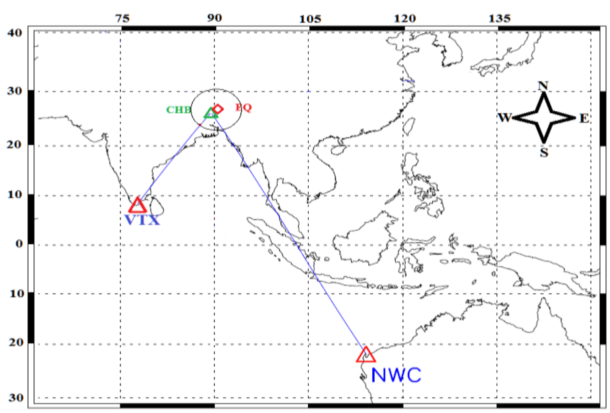


Figure 2. Show the VLF Receiving station and the VLF transmitters VTX and NWC on the Global map. EQ epicenter and the circle represent the EQ preparation zone. The blue lines are the VTX-CHB and NWC-CHB propagation paths. Green triangle indicates the VLF receiving station. Red triangles are the VLF transmitters on the Global map.

3 Results and Discussions

To identify the anomaly in the VLF signal amplitude of both the VTX-CHB and NWC-CHB path we have calculated the average diurnal variation of the month of September, 2018, taking 10 quite days with respect to natural phenomena. The $\pm 3\sigma$ of those 10 days are also calculated and compared with the each day signal amplitude from 05.09.2018 to 14.09.2018. The Kp index for the same duration were also checked to correlate with the earthquake. Figure 3 represents all these results.

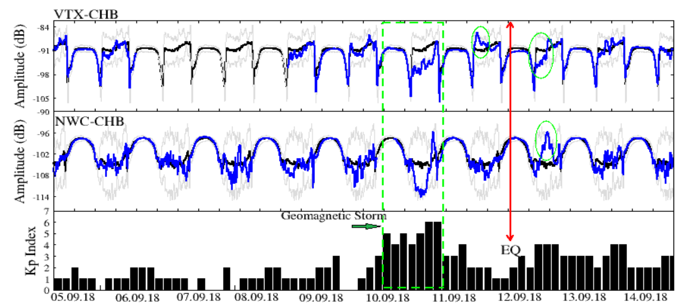


Figure 3. Red vertical line shows the EQ day. Green box represent the geomagnetic storm period. The upper panel showing VTX-CHB VLF amplitude, middle panel is for NWC-CHB amplitude compared with $\pm 3\sigma$ (gray lines) and average (black line), lower panel are the Kp index. All these data from 05.09.2018 to 14.09.2018

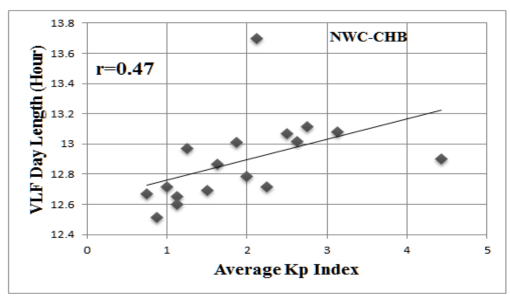


Figure 4. Correlation co-efficient graph between VLF Day length and Average Kp index along NWC-CHB path.

The VLF Day Length is the time duration from morning terminator to evening terminator of a particular diurnal variation for 24 hour. VLF Day lengths of each day are obtained to establish the correlation between the VLF signal and Geomagnetic storm effect. The correlation coefficient between VLF Day length and Average Kp index are obtained for both VTX-CHB and NWC-CHB path. A good correlation between VLF day Length and Average Kp value for NWC-CHB path is established (r=0.47), although for VTX-CHB the value is low (r=0.28).

The analysis shows actually a complicated effect of both the occurance of geomagnetic storm and the earthquake. The terminator time and amplitudes of each VLF diurnal signal for both the path are also checked and it is found that pre-seismic effects possibly are there. As there was a geomagnetic storm the pre-seismic effect may exists in a complicated way with the effects due to storm. Studies regarding geomagnetic storm induced disturbances in the ionospheric D-region as well as in the VLF amplitude have been revealed earlier, similar to our case.

There are sufficient supportive studies which include the fact that geomagnetic can trigger an earthquake. In our case we see both pre-seismic and post seismic effects and a geomagnetic storm before the EQ. So the pre-seismic effects are not only due to earthquake but it is mixed with geomagnetic activity induced influence.

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