Studies on the influence of large earthquakes (M>7) upon 9 kHz sferics recorded from Kolkata

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Abstract **- The outcome of the analyses of some significant observations in the records of VLF sferics over Kolkata (Lat. 22.56º N, Long. 88.5º E) at 9 kHz during the occurrences of large earthquake on August 14, 2021 will be presented here. Discrete spike-type signals are obtained as the precursors of this earthquake with magnitude M>7. The number of spikes and their intensities are found to vary irregularly and reached their maximum value on the day of occurrence. It then decreases gradually and finally ceased.**

Index Terms **- Earthquake, ionospheric perturbation, precursory effects, seismo-eletromagnetism.**

I.INTRODUCTION

Seismo-electromagnetic emissions are observed in ULF-ELF-VLF bands in the seismically active zones prior to the incidence of any large earthquake (Fuzinawa and Takahashi 1995; Hayakawa 2010; Sorokin *et al.*, 2007). During any large earthquake, electromagnetic radiations, chemical and gaseous particle emanations would cause ionospheric effects that modulate the electric charge distribution. These incidents are taken as the signatures of lithosphere-atmosphere-ionosphere coupling influencing the conductivity, electron density fluctuations, changes in temperature and ionic composition of the lower atmosphere (Boskova *et al.*, 1994). There is rapid enhancement in the occurrences of H_2, CO_2, CH_4 along with the increase of atmospheric radioactivity connected to the emissions of elements like radon, radium, uranium and their decay products (Biagi *et al.* 2009; Yasuok *et al.* 2012).

The August 14, 2021, Haiti earthquake was the deadlier earthquake that killed more than 2,248 people as of September 7, 2021 and injured above 12,000 people. At least 136,800 buildings were damaged or destroyed. It occurred at 12:29:09 UTC as well as at 08:29:09 Haiti local time on August 14, 2021. The strength is M 7.2 with its epicenter at Lat. 18.408^0 N, Long. 73.475^0 W, about 150 km west of the Capital, Port-an-Prince.The depth of the epicenter of the main shock is 10 km.

In this paper, the results of some significant observations at 9 kHz recorded over Kolkata (Lat. 22.56º N, Long. 88.5º E) by VLF receivers during this earthquake will be presented.

II. OBSERVATIONAL RESULTS

We detected the effects of the large earthquakes upon 9 kHz sferics from several days prior to the day of occurrence which continued for some days during the post-earthquake period.

The fractional change in the mean signal amplitude became higher in the nighttime than the daytime. For higher reflection height, the VLF signals have lower attenuation. The reduction of signal strength is due to higher attenuation at the earth-ionosphere wave guide. The variations in signal amplitude due to solar flares during the occurrence of lightning, electron density perturbation in the lower ionosphere cannot affect the decrease in daily mean amplitude and these are neglected in comparison to earthquake associated effects. Storm effects on VLF propagation show some decrease of the VLF phase and amplitude at nighttime during the main phase of storm. The parameters, eg, surface temperature; radon emanation may influence the conductivity of the lower ionosphere leading to the modification of atmospheric electric field.

In the seismoactive region surrounding the place of occurrences of the earthquakes at Haiti (Lat. 18.408^0 N, Long. 73.475^0 W), because of lithosphere-ionosphere coupling and perturbation of temperature on the earth’s surface, the atmospheric medium is further excited that move towards the ionosphere. By this, electromagnetic emissions from lithosphere propagate upwards modifying the ionosphere.

Various features are observed from the continuous records of VLF sferics at 9 kHz near Kolkata. Spiky variations at 9 kHz records are noticed during the occurrences of the earthquakes on August 14, 2021 having magnitudes M=7.2 with 10 K.m. depth at the epicenter. Fig. 1 shows the time series graph of sferics on April 01, 2021 at 9 kHz recorded at Kolkata in a normal day where no spiky variations are observed. The normal day means meteorologically and geophysically clear day and there is no occurrence of any earthquake having M>5. The figure shows the diurnal variations with sunrise and sunset effects. The commencement time of spikes is several hours earlier than the commencement of the earthquakes or around the time of their occurrences. The number of spikes per hour, i.e., the intensity of spikes varies with the earthquake. The spiky variations for the strong earthquake have been considered for analyses during August 7 – August 21, 2021.

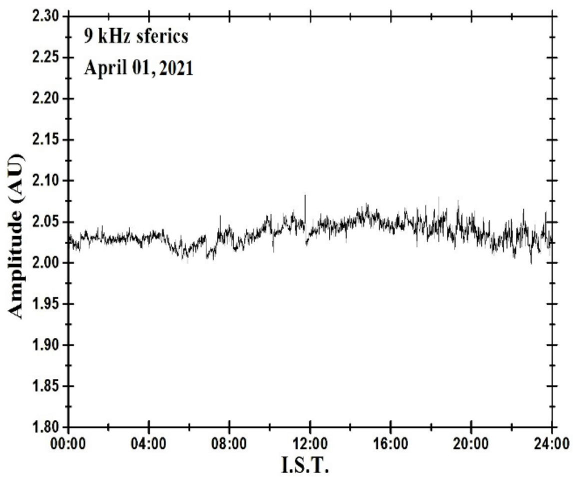

Fig.1: Normal day record of 9 kHz sferics signal observed near Kolkata of April 01, 2021, a meteorologically clear day.

Figure 2 represents the time-series graphs of amplitude of 9 kHz signals at different dates before and after the day of occurrence of the earthquake. It is seen that the commencement of spike events occurs some days prior to the strong earthquake and then decrease gradually. The variation in spike heights and the variation of total number of spikes per hour increase with the approach of the day of occurrence and reached their maximum values.

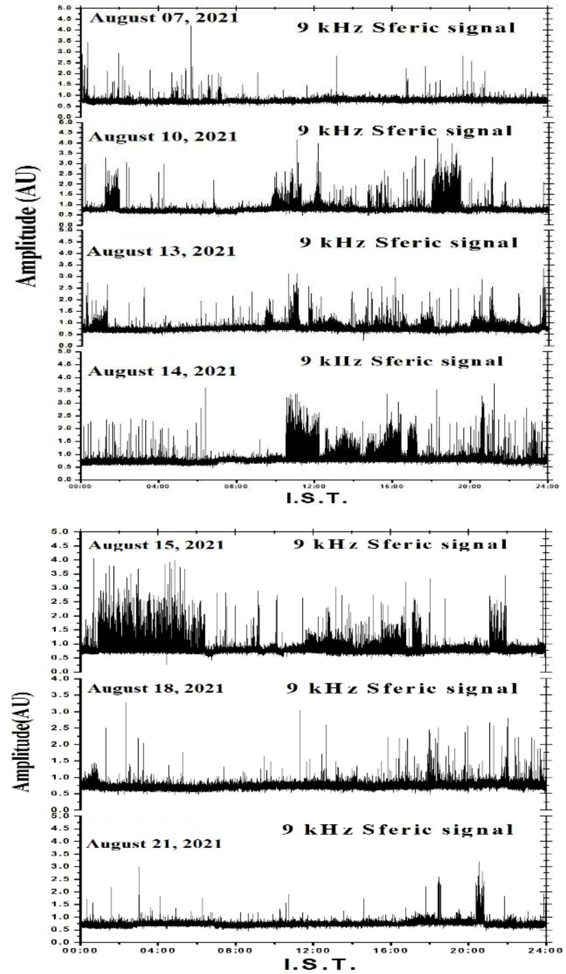

Fig.2: Diurnal variation of 9 kHz sferics signal observed near Kolkata.

The variations gradually reduce during the post earthquake period and finally ceased. In the time scale, the spikes occurred in the duration of the order of a few minutes. The experimental site is situated at a distance of 70 km from Kolkata, free from big and small industries, and dense locality. So, the occurrences of man-made and other industrial noises were absent. The power supply system for the receiver is thoroughly checked and no fault or any leakage was detected. So, the nature of the spikes does not depend on any of those causes. Also, the nature of the spikes and their characteristic separations are completely different from the local thunderstorm transient variations or from any other effects, e.g., solar flare, meteor shower, geomagnetic storms (De *et al.*, 2010). Total number of spikes per hour as observed during the month of August, 2021 for 7 days are represented by bar diagram in Fig. 3. The amplitude is maximum for the earthquake with large M value. The bars with different heights indicate the precursory and post seismic effects. The diurnal pattern observed in Fig. 1 is absent in the records of the earthquake occurrence dates (Fig. 2).

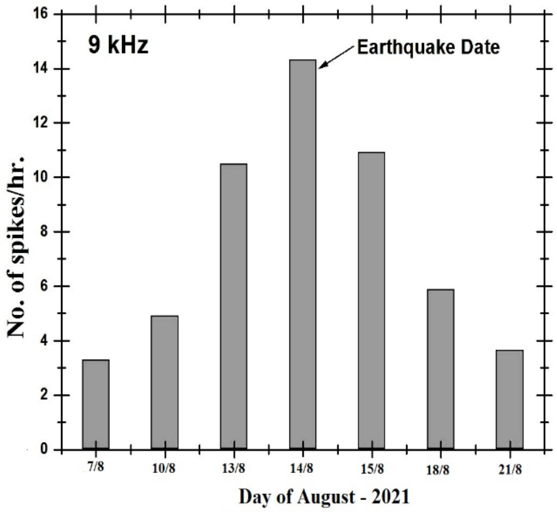

Fig.3: Variation of number of spike per hour on 9 kHz due to strong earthquakes.

III. CONCLUSION

Some characteristic features of large earthquake have been analyzed from the recorded data. Some of their aspects are shown in Fig. 2. The night time intensity and the number of occurrence of spikes are found to be much higher than the day time (Kumar *et al.*, 2013). The signal is characterized by spiky variations commencing several hours prior to the occurrence of earthquake. The nearer the epicenters from the receiver, the higher is the amplitudes of spikes. The amplitude of spikes is very much dependent on the magnitude of the earthquake.

During any large earthquake, there will be coupling between lithosphere–atmosphere and ionosphere through some probable channels, e.g., chemical channel, acoustic channel and electromagnetic (EM) channel. From chemical channel, there will be water elevation, gas emanation/radon emanation, changes in geophysical parameters which introduce chemical/conductivity changes in air resulting in a modification of the atmospheric electric field perturbing the plasma density in the ionosphere. Acoustic channel introduces excitation of atmospheric oscillations that propagate up to the ionosphere thereby modifying the ionospheric density. EM channel is supposed to introduce VLF emission, ionizations, electric charge redistribution above the surface of the earth by which anomalous electric field would be generated producing large-scale irregularities. Anomalous field propagates into the inner magnetosphere and interacts with energetic particles. These particles precipitate into the lower ionosphere initiating direct heating, liberation of exo-electrons, and/or ionization of the ionosphere by seismo-ELF–VLF waves. These are detected as precursors of any vast earthquake of large M-value.

Although any quantitative relation between the observed signals and the earthquake source parameters are lacking (Pham and Geller 2002), the claim of background noise also fails to comply with the time-series records of any observed signals during the occurrence of large earthquake.

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