On Some Effects of Perturbations in the Ionosphere due to Electromagnetic Precursory Signals from Earthquake

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***Abstract*— Electromagnetic fields due to earthquake have been studied in this presentation through some model calculations. The expressions of the variation of electron concentration and electron temperature as the ionospheric precursors of earthquake have been deduced in this presentation through quasihydrodynamic formulations.**

The outcome of the analyses of electromagnetic emissions recorded by VLF receivers at 5, 7, 9 and 12 kHz on November 16, 2008 over Kolkata (Lat. 22.56° N, Long. 88.5° E) during the large earthquake at Minahasa, Sulawesi (Lat. 1.27° N, Long. 122.09° E), under Indonesia have been presented here. Spiky variations of signals are observed few days prior to the day of occurrence of the earthquake which continued several days more, then decayed gradually and eventually ceased.

***Index Terms*—Ionospheric perturbations, precursors of earthquake, seismicity, seismo-electromagnetics.**

I. INTRODUCTION

BOTH precursory and post- seismic variations in ELF-VLF amplitude and in ionospheric parameters have been reported from satellite based observations surrounding any earthquake [1]-[4].

The study of seismic related phenomena shows enhancement of DC electric field accompanied with the generation of periodic inhomogeneities in the electrical conductivity of the lower ionosphere.

Significant perturbation in the electric field amplitude would be expected to occur in the lower atmosphere that enhances the changes in the values of lower atmospheric parameters [5]. The expressions of the variation of electron concentration and electron temperature within the medium are derived through energy balance equation, continuity equation and ionization balance equation. The equations for fluctuations of electron temperature and electron density are derived.

Also, the results of some significant observations by VLF receivers recorded over Kolkata at 5, 7, 9 and 12 kHz during the Minahasa, Indonesia earthquake occurred on November 16, 2008 will be presented. The effects of the vast earthquake (M=7.3) are exhibited through the occurrence of discrete spikes which were observed first on November 9, 2008 and continued upto November 23, 2008. Both number of spikes and their intensities as well as durations were found to be changed irregularly and reached the maximum value on the day of occurrence. The signatures ceased gradually and almost ended after November 23, 2008. These commencements may be considered to be precursory and post-seismic effects of this vast earthquake [6]. The records were taken at Kolkata which is about 2400 km away from the place of occurrence. The effects at 5 and 7 kHz have been found to be remarkably higher than at 9 and 12 kHz. The VLF signals are processed and being stored in a computer. The r.m.s. value of the filtered data are analyzed regularly using Origin 5.0 software.

II. MATHEMATICAL FORMULATIONS

The effects of electromagnetic field due to earthquake on the variations of ionospheric parameters, the following equations are chosen:

$$N\frac{\partial\vec{v}}{\partial t}+N(\vec{v}.\nabla)\vec{v}=\frac{e}{m}N\vec{E}(t)-N\nu_e(T_e)\vec{v}-\\-\frac{\nabla p}{m}-\eta\nabla^2\vec{v}-\frac{eN}{m}(\vec{v}\times\vec{H}) \tag{1}$$

$$\frac{3}{2}\frac{\partial}{\partial t}(NkT_e)+eN\vec{v}\cdot\vec{E}+\frac{3}{2}\delta\nu_e(T_e)\\ Nk(T_e-T)-\nabla\cdot\vec{W}+Q_i\frac{\partial N}{\partial t}=0 \tag{2}$$

$$\frac{\partial N}{\partial t}=q_i+\nu_{de}\lambda N-\nu_\alpha N-\alpha_r N^2(1+\lambda)+\\+\frac{\partial}{\partial z}\{(D_t+D_\alpha)\frac{\partial N}{\partial z}\} \tag{3}$$

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$$\frac{\partial N^+}{\partial t} = q_i - \alpha_r N^2(1+\lambda) - \alpha_i N^2 \lambda(1+\lambda) + + \frac{\partial}{\partial z}\{(D_t + D_\alpha)\frac{\partial N^+}{\partial z}\} \quad (4)$$

$N^+ = N + N^-$

Where, q_i, the ionization rate; ν_{de}, the effective electron detachment rate from the ions; ν_α, the rate of electron attachment to neutrals and Q_i, the ionization energy of the plasma medium. $\vec{v}$, the average electron velocity; N, electron number density; $\delta = \frac{2m}{m'}$, m' the mass of the heavy particle; T, the equilibrium temperature; η, the coefficient of viscosity and $\vec{W}$ is the heat flow vector. It is expressed as

$$\vec{W} = -\chi(T_e)\nabla T_e \quad (5)$$

Where, $\chi(T_e)$ is the effective coefficient of electron energy conduction.

$$\lambda = k_T(1 - \mu\tau' / \sigma_0 k_T) \quad (6)$$

k_T, the coefficient of electron energy conduction at constant electron velocity; μ, the coefficient of electron energy conduction due to dc electric field; τ', the current flow coefficient due to thermal gradients at constant pressure, $p = NkT_e$ and σ_0 is the dc electrical conductivity. The other symbols have their usual significance. From (5) and (6), the expected changes in temperature and number density at different heights due to precursors at the active regions of the ionosphere can be estimated numerically.

III. RESULTS AND DISCUSSION

The expressions for the fluctuations of electron temperature and density within the upper atmosphere in the absence of electric field due to earthquake have been deduced from the previous equations as:

$$\frac{\partial \Delta T_e}{\partial t} + \frac{1}{\delta \nu_e T_e}\left[q_i + \Delta N(\nu_{dc}\chi - \nu_\alpha) + N_0 \delta \nu_e(T_e) - -\alpha_r(i+\chi)N_0^2\right]\Delta T_e = \Delta N \delta \nu_e(T_e) - \frac{2Q_i}{3kT\delta\nu_e(T_e)}$$

$$\left[q_i + (\nu_{de}\chi - \nu_\alpha)N_0 + (D_t + D_\alpha)\frac{\partial^2 N}{\partial z^2} - \alpha_r(1+\chi)N_0^2\right]$$

$$+\frac{2e^2\Delta N}{3mkT\delta\nu_e(T_e)}\vec{E}\left[\exp\left\{(-A) + \frac{e}{m}\int_{t'}^{t} Xdt''\right\}\right]$$

$$\left[\int_0^t \vec{E}(t')\exp\{1 + \frac{e}{m}\int_{t'}^{t} Xdt''\}dt'\right]$$

Where

$\tau = \delta\nu_e(T_e)t$, $N = N_0 + \Delta N$, $T_e = T_{e0} + \Delta T_e$

and,

$$\frac{N_0 k(T_e - T)}{m}\frac{\partial^2(\Delta N)}{\partial z^2} + \frac{2Q_i}{3kT_e}\left[(D_t + D_\alpha)\nu_e(T_e)\right]$$

$$\frac{\partial(\Delta N)}{\partial z} = \frac{\partial^2(\Delta N)}{\partial t^2} - 2\alpha_r N_0(1+\chi)\Delta N - \frac{3}{2}\frac{N_0 k}{m}\nu_{de}$$

$$\frac{\partial^2}{\partial z^2}(T_e - T) + 2\nu_{de}\chi\frac{\delta(\Delta N)}{\partial t}$$

The magnitude of the temperature enhancement and decrease in the electron density may be estimated using satellite data from the earthquake (M>4.5) zone. Seismo-electromagnetic emissions have been observed at low frequency bands in the seismically active zones prior to the incidence of any large earthquake [7] which are different from lightning induced and technogenic emissions.

IV. OBSERVATIONS

From the VLF sferics at 5, 7, 9 and 12 kHz which are simultaneously recorded at Kolkata round-the-clock, various features are observed. In the month of November, 2008, some days prior to the vast earthquake at Minahasa on November 16, 2008, remarkable spiky variations at 5, 7, 9 and 12 kHz records are observed. The spikes are found to appear first on November 9, 2008. Number of spikes per hour above the ambient level was found to be very large and the height of spikes above the ambient value is also remarkably high. The huge magnitude of spikes commenced a few days prior to the day of occurrence of the earthquake. It may be realized as the precursors of the earthquake. The intensity of spikes gradually reduced and almost ceased after November 23, 2008. The typical records of sferics at 5, 7, 9 and 12 kHz on the day of occurrence of earthquake on November 16, 2008 and one day before the occurrence (November 15, 2008) are shown (Figs. 1 and 2). The spikes in Fig. 2 is less prominent relative to the spikes observed on the day of occurrence.

The characteristic parameters of the earthquake have been determined by statistical spectrum analyses of the recorded data for the period November 8, 2008 to November 24, 2008. The variations of spike intensity per hour before and after the earthquake have been depicted by bar graphs in Fig. 3. It is seen that on the day of occurrence, the response at 5 and 7 kHz is much higher than at 9 and 12 kHz. Both precursory and post-earthquake effects are found to be different at these four frequencies.

The earthquake occurred along with 12 after-shocks on the same day and almost at the same place having M: 3.7 to 5.6. Different quakes due to after-shocks are of various magnitudes and their hypocenters are located at different depths. As a result, the electromagnetic signals which are thought to be generated during the period get attenuated differently for different sources. The uneven distribution of intensity of spikes in Fig. 3 may be due to anomaly in the after-shock effects which were present during the period.

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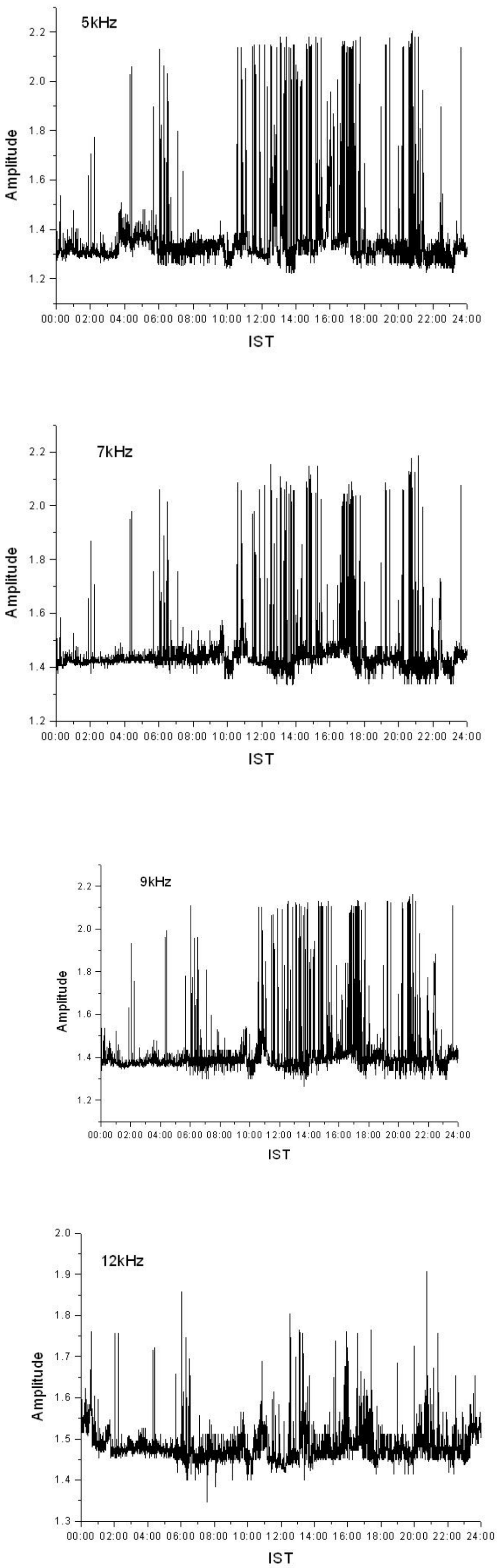

Figure 1. Diurnal variation of Sferics observed on November 16, 2008.

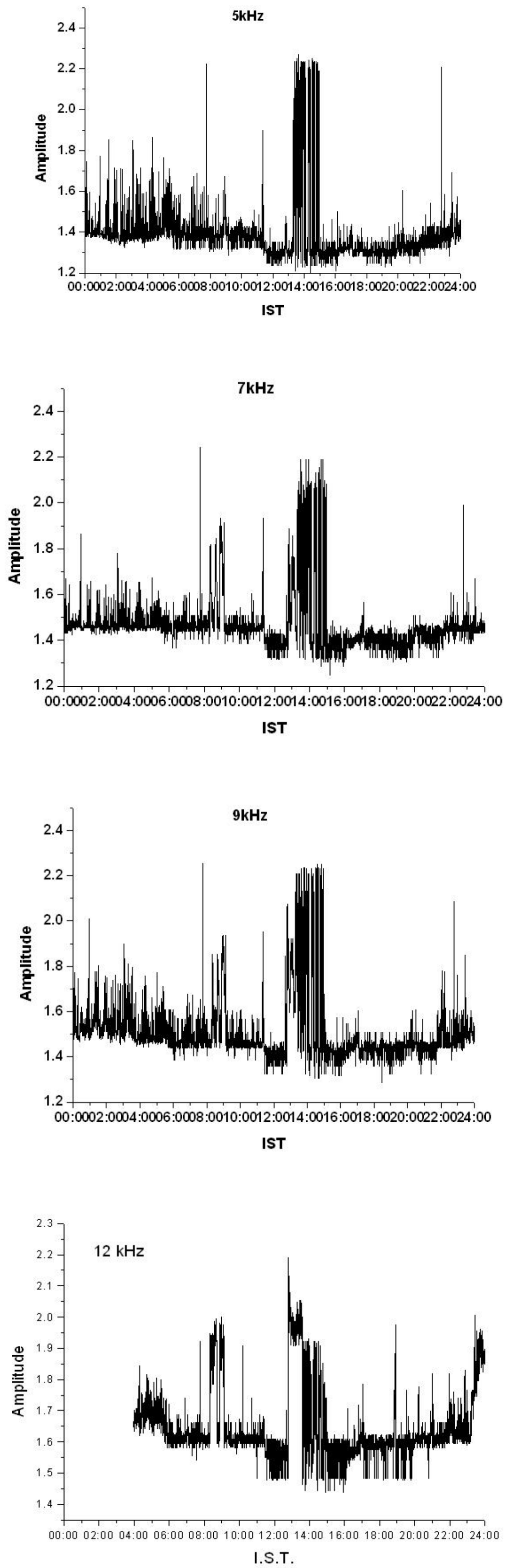

Figure 2. Diurnal variation of Sferics observed over Kolkata on November 15, 2008.

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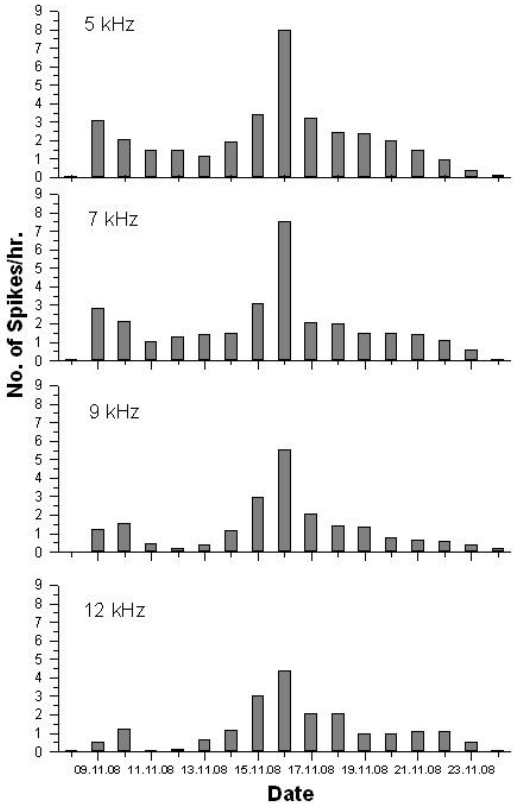

Figure 3. Variation of spike intensity per hour before and after earthquake.

V. CONCLUSIONS

The prediction of earthquake through the precursory effects from the recorded sferic signals can be made nearly ten days earlier than the day of occurrence of the earthquake. Usually, the earthquakes having M>6.0 show predictable signatures over VLF sferics in most of the circumstances.

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