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Variation of Schumann resonance frequency observed at Allahabad (Lat 22°N, Long 81.51°E)

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The lightening bolts throughout the Earth stimulate the cavity between the Earth's surface and lower ionosphere to resonate at extremely low frequency (ELF). This causes the Earth's magnetic field to oscillate at these frequencies and the phenomenon is known as Schumann resonance (SR). Theoretically, the harmonics of the oscillations are found to be at approximate frequencies of 7.8, 14, 20, 26, 33, 39 and 45 Hz, which depend on the conductivity of the lower ionosphere, conductivity of the ground and different propagation properties of the Earth-ionosphere cavity. With the improved sensitivity, accuracy and sampling rate of the search coil magnetometer installed at low latitude (Allahabad, lat 22°N, long 81.51°E), the characteristics of SR frequency have been studied and presented.

Keywords: Schumann resonance frequency, Lightening bolt, Geomeagnetic field variation

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1 Introduction

Among the wide band of electromagnetic (EM) radiation generated by about 2000 thunderstorm cells, permanently active around the Earth which produce 50 lightening events every second[1], the extremely low frequency (ELF) band (3-300 Hz) is trapped between the cavity of Earth's ground and the lower ionosphere. These two act as natural wave guide for the ELF wave producing resonance inside the cavity as the circumference of the Earth is nearly equal to the ELF wavelength. This phenomenon is named as Schumann resonance (SR) after the name of Schumann[2] who first predicted it. SR was experimentally detected several years later by Balser & Wagner[3]. The radio wave traveling along the ground surface circles the globe and return to the starting point. The first or the basic SR occurs when the phase delay of the round the wave is equal to 2π. Theoretically, the SR maxima are found nearly at 7.8, 14, 20, 26, 33, 39 and 45 Hz (refs 4-6).

From the two scale height conductivity model, the resonance frequency is defined as:

$$f = 7.49\sqrt{l(l+1)\frac{h_1}{h_2}}$$

where, l, is the mode number; h_1, the conduction layer height; and h_2, the reflection layer height.

In deducing the SR theory, the surface of the Earth is considered as perfect conductor in comparison to the lower ionosphere. Hence, the characteristic of the SR is extremely dependent on the lower ionosphere[7]. With the variation of solar activity, the ratio of conduction layer height to reflection layer height changes and hence, the SR frequency also changes[8,9]. The regular variation of SR frequency may arise from the combined effect of day and night asymmetry and the eccentricity of the geomagnetic field[10]. The motion of the thunderstorm activity with respect to the observational site cause the amplitude variation of the signal and hence, induce changes of both peak frequency and Q factor of SR modes[10]. The SR intensity variations arise because of the variations in strength of the thunderstorm, height of the Earth-ionosphere cavity and on the variations of source observer distance[11].

In the present paper, the frequency characteristics of SR have been examined using spectral analysis technique on the data of geomagnetic field variation collected from search coil magnetometers.

2 Instrumentation and Data analysis

The instrument consists of 3-channel search coil magnetometers acquired from Lviv Centre of Institute of Space Research, Ukraine. The instrument was deployed at a subtropical station Allahabad (lat 22° N, long 81.51° E). It consists of three search coils that record geomagnetic field variations in three orthogonal directions, viz. N-S (X component), E-W (Y component) and vertical. These coils are buried under ground up to 3 ft to minimize local vibration and temperature effect. Data is downloaded with the help of communication unit where the data cables from all the three coils are connected. Time synchronization is obtained by GPS receiver antenna which is connected to the communication unit. The sampling frequency of the instrument can go up to 256 Hz but the instrument was operated at sampling rate of 64 Hz to save the memory. The instrument can record signal of frequencies up to 32 Hz and therefore, one can study right from geomagnetic pulsations up to ELF band. Down-sampling and filtering of the data may be required depending upon the frequency band one wants to study.

In the present case, the data during March-December 2005 has been examined. The data is transformed from geomagnetic to geographic co-ordinate. As the phenomena of SR depend on the geographical location, it is more relevant to work with the transformed data in geographical coordinates. It may be pointed out that the site does not provide quiet electromagnetic environment and there is inherent noise close to frequencies of different SR harmonics. Nevertheless, it was possible to get the frequency characteristics of SR for second harmonics and beyond. The noise is much more pronounced near the first harmonic and hence, one can do away with it. The static spectra were prepared by Welch method, by taking 1 h data (230464 data points), and window of 1024 data points with sliding of half the window. In this method, each spectrum is the average of the 514 spectra each of 7 sec. The final spectrum has been smoothed taking running average of 5 points. These reveal the SR of 2nd harmonic onwards nicely.

3 Results and Conclusions

Figures 1 and 2 show the power spectra revealing SR for the month of March, June, September, and

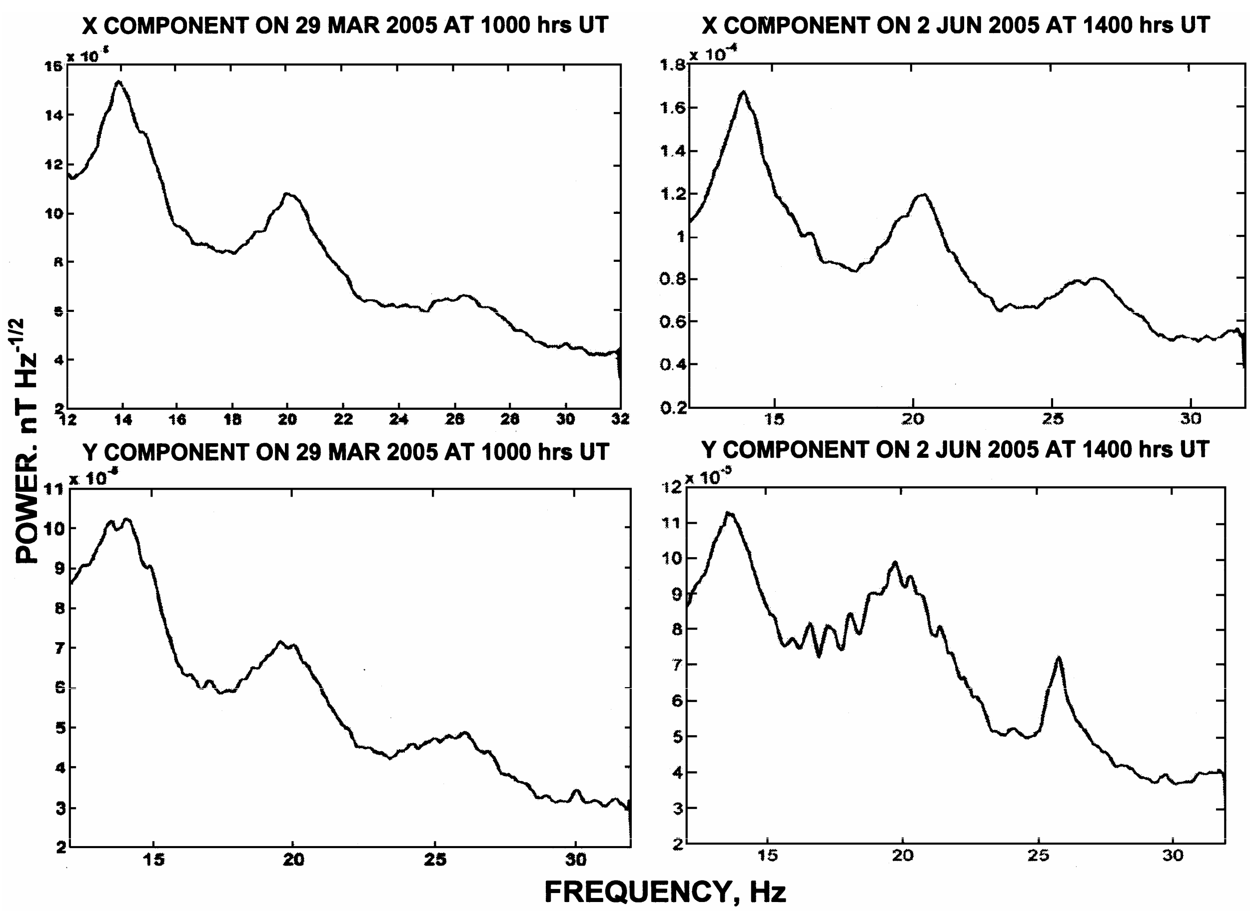

Fig. 1 — Static spectra of variation of magnetic field of ELF waves of geographic N-S (X) and E-W (Y) component on: (Left panel) 29 March 2005 at 1000 hrs UT; and (Right panel) 2 June 2005 at 1400 hrs UT

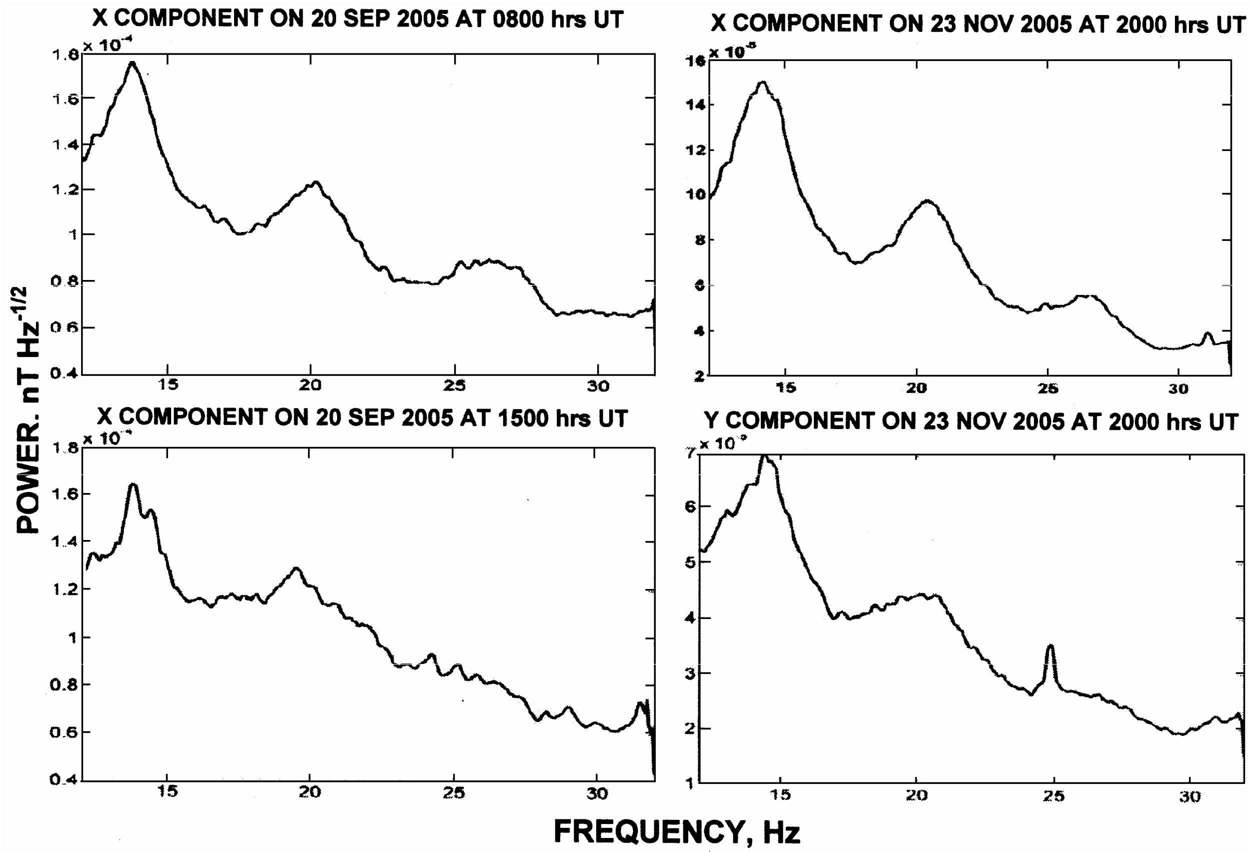

Fig. 2 — Static spectra of variation of magnetic field of ELF waves of: (Left panel) Geographic N-S (X) component on 20 September 2005 at 0800 and 1500 hrs UT, respectively; and (Right panel) Geographic N-S (X) and E-W (Y) component on 23 November 2005 at 1400 hrs UT

November 2005 (one day of each month is shown). The second, third and fourth harmonics of Schumann spectra are observed at 14, 20 and 26 Hz, respectively. Noise present at nearly 25 Hz distorts the 4th harmonic of SR peak as shown in lower part of the right panel of Figs 1 and 2. It has been observed that the power in the N-S (X) component is greater than the power in the E-W (Y) component throughout the year. The N-S component (X-component) of magnetic field is affected by the signals coming from E-W direction and E-W component (Y-component) of magnetic field is affected by signal coming from N-S direction. The dominance of power in N-S component of SR indicates that in the Indian zone, ELF waves generated from thunderstorm activities in the south-east Asian region dominate more as compared to African and American sectors. Spectra also show the seasonal dependence of amplitudes as well as the frequency. The dependence of intensity of SR on the location is well known, but one cannot look into this aspect with the single station measurements. This will be clearer if one has more number of stations. Indian Institute of Geomagnetism has a comprehensive plan of setting up a network of search coil measurements in Indian sector. With the network of stations, it will be possible to work out the source location and the propagation characteristics of ELF waves.

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