HIGH ENERGY SOLAR PARTICLES INDUCED ANOMALIES IN THE FIRST MODE SCHUMANN RESONANCE FREQUENCY

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Abstract

Effect of X-ray bursts occurred on 22 September, 2011 (followed by solar proton events (SPEs)) on the variation of first mode Schumann resonance (SR) frequency monitored at a low latitude station, Agra (Geograph. lat. 27.2^{o}N, long. 78^{o}E), India is examined. The variation of average first mode SR frequency shows a sudden increase in coincidence with the X-ray bursts and a decrease associated with the peak flux of SPE. The increase in the frequency is interpreted in terms of growth of ionization in the upper part of D-region ionosphere due to X-ray bursts and decrease is interpreted in terms of low ionization due to reduction in the height of the D-region ionosphere in the polar region. The variation of SR frequency is observed to be consistent with other observatories at middle and high latitudes.

1. Introduction

The extremely low frequency (ELF) waves radiated from lightning discharges propagate in the earth-ionosphere cavity around the globe and give rise to Schumann resonance (SR) phenomenon. The SR phenomenon is characterised by resonant lines caused by standing waves at the frequencies of 8, 14, 21, ….Hz and have been extensively studied in relation to global thunderstorm activities, ground surface temperature and lower ionosphere etc. because of their intimate relationship. An excellent monograph on theoretical and experimental background of this phenomenon has been presented by [1].

The SR waves propagate around the globe after multiple reflections between the ground (and the sea) surface and lower boundary of the ionospheric D-region. Since the ground (and sea) are considered to have very large conductivities as compared to the ionosphere, whatever changes that may occur in the characteristics of SR and other ELF/VLF waves are due to structural changes in the ionosphere [2,3,4]. It is for this reason that many changes in the characteristics of SR phenomena have been interpreted in terms of changes in the ionospheric characteristics caused by various geophysical phenomena. For example, a solar flare provides the X- rays and gamma rays which hit the lower ionosphere in the day side and cause sudden ionospheric disturbances (SID), and two kinds of particles (high energy protons and electrons) which penetrate through the magnetosphere and ionosphere and precipitate in the polar cap regions both in the day and night side of ionosphere causing ionisation changes in D and E regions [5,6]. The 11-year solar cycle changes are found to influence the SR phenomena significantly, specially during the decreasing phase of the cycle when the first mode frequency decreases [7,8]. Anomalies in the SR bands have been reported by Hayakawa et al. [9] and Nickolaenko et al. [10] in which they found increase in the intensity of fourth harmonic due to earthquakes which are interpreted in terms of superposition of direct ELF signals from a distant thunderstorm source and those scattered from a conducting disturbance in the atmosphere over the epicentre of the earthquake.

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In this paper, we present some more evidences of effects of X-ray bursts and solar proton events on the lower ionosphere in the polar region and their consequent effects on SR phenomenon.

2. Experimental Setup and method of data processing

We have employed a set of 3-component search coil magnetometer (LEMI-30) which was imported from LVIV center of Institute of Space Research, Ukraine basically for studies of ULF/ELF emissions associated with earthquakes. Since the dynamic frequency range of the magnetometer is from 0.001 to 30 Hz, it can very well record and display the SR lines in a relatively noise-free area. The 3-sensors are oriented in geographical North-South (X-component), East-West (Y-component), and vertical (Z-component) directions and are separated from each other to avoid interference between them. The complete set up is similar to the one used by us earlier [11].

3. Analysis Results

In order to examine the variation of first mode SR frequency on 21 September event, we superimpose the first mode SRvariation on the same time format as used for X-ray bursts and SPEs and the results are shown in Fig. 1. It is seen that the SR frequency increases from its mean value of 7.35 Hz to the maximum of 7.97 Hz (increase ≈ 8.4%) and the peak value coincides with the peak of the X-ray intensity. Then the frequency decreases to its normal value, increases slowly again, then dips to its minimum value of 7.03 Hz (decrease ≈ 4.3%) in coincidence to the peak value of SPE around 0900 UT on 23 September.

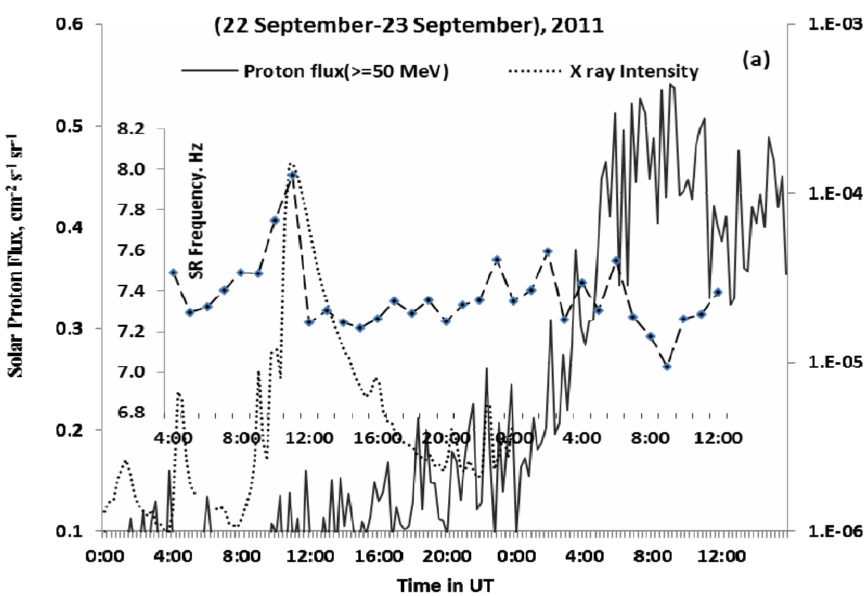

Fig.1:Temporal variation of X-ray burst and solar proton event occurred on 22 September, 2011, and the variation of first mode SR frequency (shown by dash - solid square).

In Fig.2 we show the variations of average first mode SR frequency for the month of September, 201. The horizontal lines in the figures indicate the mean (m) and standard deviation around the mean (m $\pm$ σ). It may be seen clearly that the frequency enhancements and decreases on 22 September is much above and below those of the specified statistical limits (m$\pm$σ) confirming that they are caused by the X-ray and SPE events.

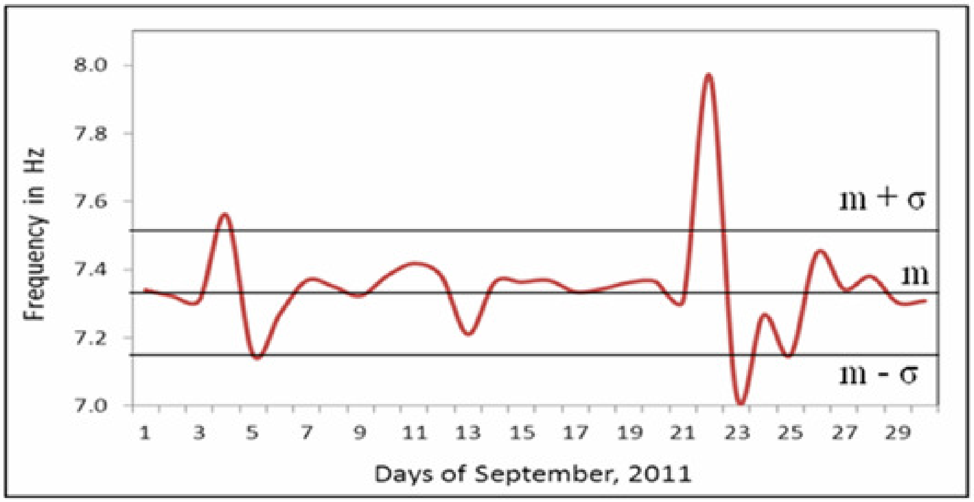

Fig. 2: Variation of daily average of first mode frequency of SR during the month of September, 2011.

4. Conclusion

Variation of daily average first mode SR frequency deduced at a low latitude station Agra is examined in the light of X-ray bursts of X1.4 occurred on 22 September 2011 followed by SPEs of 10-100 MeV range energy. We find that the SR frequencies are enhanced (8.4%) in coincidence with the X-ray bursts but decreased (4.3%) with minima coinciding the peaks of proton events. The results are interpreted in terms of growth of ionization at higher D-region altitudes due to X-ray bursts causing enhancement of first mode frequency, and additional ionization in the reduced D-region

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