Dynamical evolution of Schumann Resonance frequency spectra during some strong Q-bursts

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Abstract

Schumann resonances (SR) observations from a tropical region near Kolkata at the estuary of the river Ganges merging into the Bay-of-Bengal (21.48° N, 88.61° E) are being made frequently. Several Q-bursts spectra are observed. Strong ELF transients are detected in the recorded data of SR. The dynamic evolution of electric and magnetic field components of the Q-bursts will be presented in this paper. Time series evolutions of signals of several Q-bursts are analyzed in the present study. It is observed that, the Q-burst amplitudes from 1 to 300 Hz of Q-bursts spectra for 1 sec FFT reaches about -47 dB near the first mode of SR frequency. This shows that Q-burst has the tendency to dominate within 1 to 300 Hz.

1. Introduction

The term Q-burst related to discrete natural ELF radio pulses detected worldwide and lasting for 0.3 to 1 sec [1]. These transient events (ELF transients) originate from powerful return strokes of lightning that provide signals well above the Schumann resonance (SR) background by a factor of about 10 [2, 3]. Strong transient ELF signals (Q-bursts) were observed in the records of first mode of Schumann resonance spectra at the estuary of the river Ganges merging into the Bay-of-Bengal (21.48° N, 88.61° E) at about 125 km south of Kolkata (22.56° N, 88.5° E). These were associated with large positive ground flashes observed locally. The magnetic field components were recorded by a square-loop antenna. The vertical electric field has been measured by using a ball antenna.

Q-burst is a solitary large amplitude damped transient electromagnetic wave emitted from the large positive polarity lightning stroke [4]. The largest charge moment changes are associated with the positive cloud-to-ground strokes that simultaneously produce sprites and Q-bursts in the Earth-ionosphere cavity.

Resonances within the Earth-ionosphere cavity are mainly excited by globally occurring cloud to ground lightning flashes. Schumann resonance transients are related to luminous events of spectacular optical flashes in the upper atmosphere above the active thunderstorms [5, 6].

Ionospheric current system in the region of higher ionization produced by lightning discharges can produce ULF magnetic field transients of magnitude and duration which are observed in association with the sprite associated lightning discharges. Mesospheric sprite phenomena are often coincident with both large amplitude positive cloud-to-ground lightning and transient SR excitations of the entire earth-ionosphere cavity producing Q-bursts. These observations are supportive for the triggering of sprites following rapid removal of large quantities of positive charge from the extensive charged layer of MCS causing mesosphere to dielectric breakdown. MCS is an exceptional meteorological phenomenon. When MCS would be found to be coincident with positive CGs in the regions of stratiform precipitation, very large peak currents which may be coincident with SR-Q-bursts, producing large dipole moment changes and yielding large discharges.

Both SR transients (Q-bursts) and sprites are excited by the same +CG discharges. About 80% of ELF bursts are associated with sprites. Large +CG discharges simultaneously excite both the Earth-ionosphere cavity resonances and the sprites. So Q-bursts may be treated as the good sensor of sprite activity in the world [7].

Source to observer distances (SODs) of Q-bursts are determined by analyzing the wave-forms [8]. The combination of direct and antipodal pulses from a source of lightning discharges produces Q-bursts. The technique utilizes the characteristic spectral pattern in the pulse spectra conditioned by the interference between direct and antipodal radio waves arriving at the observer.

Q-bursts are believed to be the signature of the impulsive excitation of the Earth-ionosphere cavity by large lightning currents. Positive cloud to ground lightning discharges produce strong radio noise (bursts) in the frequency range from few Hz to several hundreds of MHz. Within the radio noise bursts, the large amplitude electromagnetic

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transient pulses in ELF (3 Hz-3 kHz) range can propagate over long distances through the Earth-ionosphere waveguide with very low attenuation rates (≈ 1dB/Mm). Lightning sources excite the TM modes within the cavity causing impulsive increase of vertical electric field and horizontal magnetic field components of the normal modes at their characteristic frequencies. The cavity is being continuously excited. In fact, the Schumann resonance spectra can be said to be the incoherent superposition of many small lightning excitations.

The continuous lightning discharges within the cavity and distribution of current moments may reach towards a situation when any sudden large lightning stroke would excite the cavity to a very large amplitude of vertical electric and horizontal magnetic field components above the existing back ground, then a discrete well-defined event, i. e., Q-bursts would occur [3, 8, 9]. Q-bursts occur occasionally. The amplitude of these types of bursts dominates over the SR modes excited by extremely large lightning strokes. Many transient bursts occur with transient luminous events (sprites) in the mesosphere. In the Schumann resonance mode, the frequency 8 Hz is influenced by Q-bursts which are purely damped oscillations and these types of bursts exist 0.3-1 sec. Some Q-bursts are found to be associated with sprites.

In this paper, the records of sudden enhancements in the amplitude of the first mode of Schumann resonance spectra are taken from our field-site. Some of the recorded data are identified as Q-bursts, the characteristics of which are presented.

2. Experimental Setup

2.1 Square-loop Antennas

It is erected for the detection of the magnetic components of the ELF signals. A co-axial cable of length 30 m is used to transfer the signal from antenna to the input of the receiver where it is pre-amplified. The frequency selective stages are designed with active circuit elements. A wide-band amplifier whose output is taken through an active low-pass filter having cut-off frequency nearly 35 Hz further amplifies it. This signal information is now stored in a computer by the data acquisition process in which a 40 Hz generator is used to convert the analog signal into digital signal. A wide-band very low input voltage sensitive and low frequency sensitive receiver has been designed which can detect the input signal.

2.2 Ball Antenna

A ball antenna made of stainless steel having 30 cm in diameter set-up at a height of 7 m above the ground. The ELF to VLF electric fields is measured regularly with this ball antenna for about three hours within 04:00 – 09:00 hrs UT during the tranquil period in the global lightning activity. The ball antenna has the frequency response from 1 Hz to 12.5 kHz. Quite a good number of Q-bursts have been obtained with transient pulse oscillations lasting more than 0.2 second, which are selected for analyses. Signals which are received by the antennas are introduced directly to a computer through a AD converter (44 kHz).

3. Analyses

Q-bursts are isolated damped oscillations lasting 0.2 to more than 1 sec at the frequency 8 Hz, the first SR mode. Lightning discharges which produce Q-bursts are of positive polarity in 85% cases and negative polarity in 15% cases.

The general form of a Q-bursts giving damped harmonic waves is shown in Figure 1. It occurred on July 4, 2000. Plot of H (North-South) and D (East-West) components of the ELF data during this burst between 06:32:47.0 – 06:32:47.6 hrs UT are shown. The same Q-burst had also been recorded at the Syowa station in Antarctica (69.0° S, 39.6° E) between 06:32:46 – 06:32:49 hrs UT, depicted in Figure 2. The time lag is about 20 msec due to the difference in the source-to-observer distance. The plots of H (North-South) and D (East-West) components of ELF data recorded on December 24, 2009 during 04:04:10.8 – 04:04:13.8 hrs UT are shown in Figure 3. A series of pulses coming at the observing station have been chosen for the electric field from a lightning stroke on the Earth as the source of Q-bursts, which exhibit nearly three-pulse-type Q-bursts between 04:04:12.0 and 04:04:12.6 hrs UT on December 24, 2009 (Figure 4). It is alike with the work of an earlier observation [9]. Two sharp positive pulses are seen. The first pulse is at 04:04:12.30 hrs UT and the second pulse at 04:04:12.43 hrs UT. The time interval between the two pulses is measured as 130 msec. The first pulse is interpreted as the direct wave and the second pulse may be the antipodal wave from the causative lightning stroke. The source-receiver distance is estimated as 6.5 Mm from the time interval between the two pulses following a previous method [9].

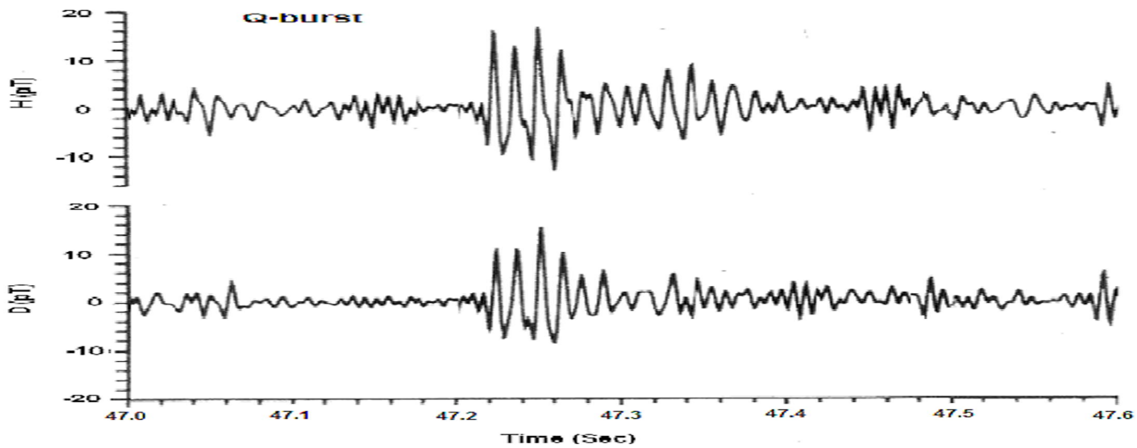

Figure 1. Plots of H (North-South) and D (East-West) components ELF data recorded near Bay-of-Bengal on July 4, 2000 between 06:32:47.0 and 06:32:47.6 hrs UT

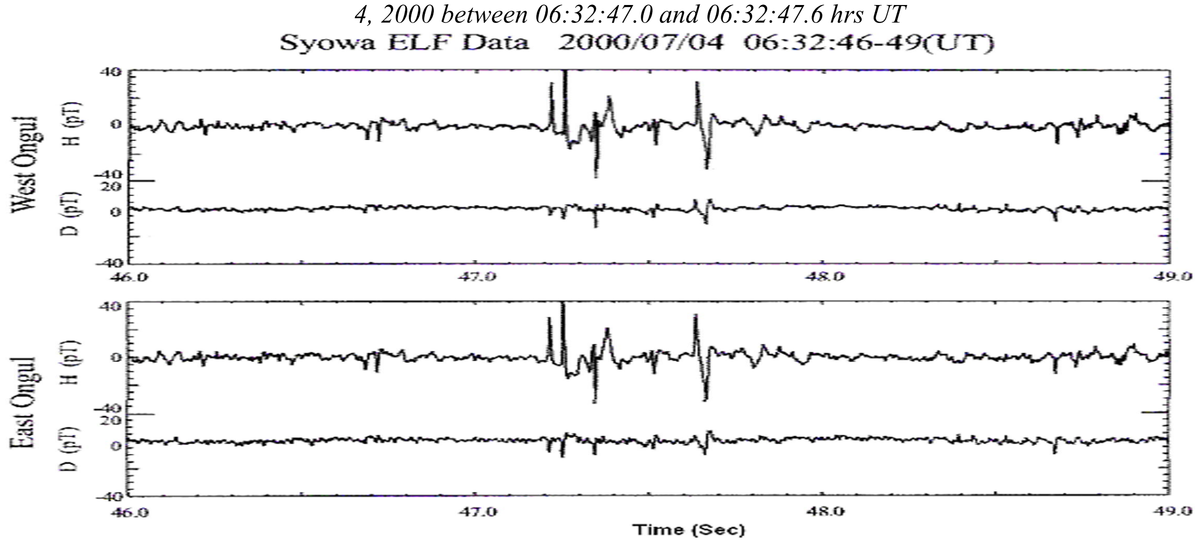

Figure 2. Plots of H (North-South) and D (East-West) components of ELF data recorded at Syowa station on July 4, 2000 between 06:32:46 and 06:32:49 hrs UT

4. Conclusion

Data for the determination of electromagnetic fields of Q-bursts at this latitude are important. The waveforms of some 45 Q-bursts have been obtained, only several of which are analyzed in the present study. The VLF wave velocity is determined and using this, SODs has been found out. The mean wave velocity is calculated through a previous work [9].

The received waveforms on Q-bursts are characterized by higher amplitude sharp initial pulses and then followed by damped oscillations. These features of Schumann resonance transients are consistent with the characteristics of Q-bursts. The observed Q-bursts dominated over the first Schumann resonance mode and caused likely by positive cloud to ground discharges followed by large current moments and longer continuing currents.

1 sec FFT of ELF spectra during Q-burst in the frequency range 1 to 300 Hz yield about -47 dB gains near the first mode of SR. As such, the existence of Q-burst within 1 to 300 Hz is expected. Q-bursts are produced by +CG lightning discharges followed by a large current moments and large continuing currents. The charge moments Qdl of (200-2000) C.km are sufficient to trigger conventional breakdown at sprite heights of ~70-90 Km.

In this tropical region, SOD is comparatively much lower due to which only the three pulse types of Q-bursts are detected from our observation station, which agrees with earlier results [9]. The probability of detection of other types of Q-bursts is very poor [10]. It is found that the observed signal strength of the detected Q-bursts at this centre exhibits lower values for higher resonance frequencies.

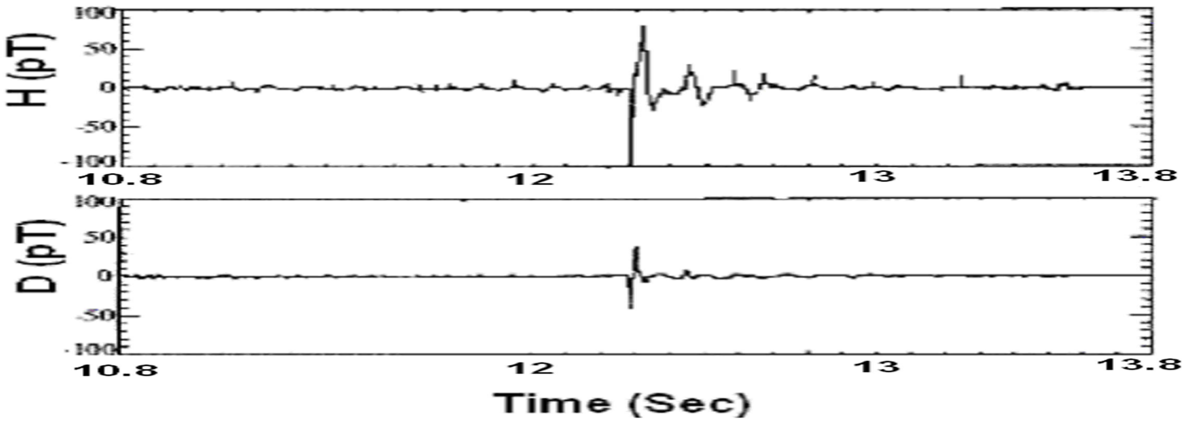

Figure 3. Plots of H (North-South) and D (East-West) components of ELF bursts recorded near Bay-of-Bengal on December 24, 2009 between 04:04:10.8 and 04:04:13.8 hrs UT. The time difference between the direct and antipodal pulses is about 130 msec

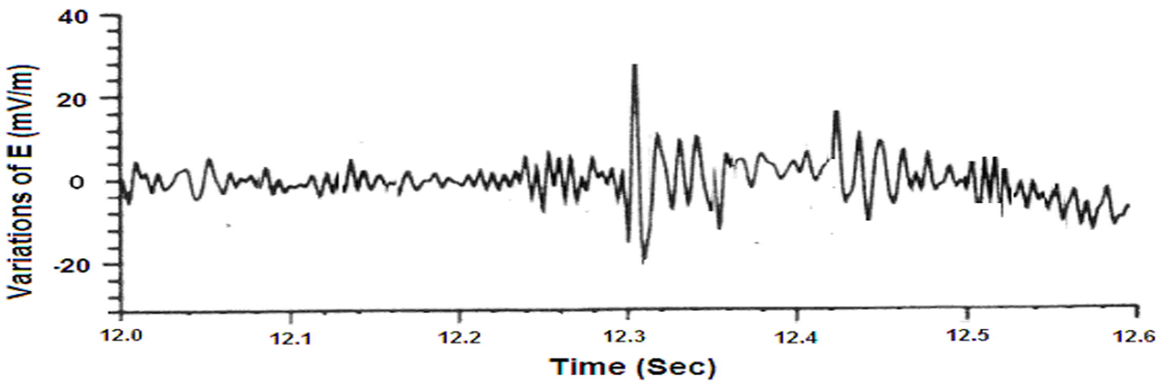

Figure 4. Plots of Electric field component of ELF bursts recorded by ball antenna near Bay-of-Bengal on December 24, 2009 between 04:04:12.0 and 04:04:12.6 hrs UT

5. References

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