Characteristics of Schumann Resonance as Observed in the Indian Sector

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Abstract. Schumann Resonances (SR) are lightning generated global electromagnetic modes in extremely low frequency (ELF) range operating in the Earth-ionosphere cavity. The 1st harmonic is at nearly 7.8 Hz and subsequent harmonics are separated by approximately 6 Hz.The phenomena have not been extensively studied in the low and equatorial regions. In this paper an attempt has been made to study the characteristics of SR in the low latitude Indian sectors using ground magnetic data from searchcoil magnetometers operating at Shillong (geographic co-ordinate lat $25^0$34', long $91^0$53', declination=-0.474^0). The diurnal pattern of amplitude of a particular harmonic show the dominance of thunderstorm activities in three major sectors viz. south-east Asia, Africa and South America. Sunrise effects are clearly seen as increase in the SR amplitude during local sunrise time. Sunset effect (decrease in SR amplitude during the local sunset time) is also observed in the East-West component, whereas for North-South component is completely masked by the global thunderstorm dominance during that time.

1. Introduction

SR is the resonance produced in the Earth-lower ionosphere cavity by the extremely low frequency (ELF) waves (3-300Hz). The condition of the resonance is that the circumference of the Earth is nearly equal to the wave length of the ELF wave (nearly 40,000 K.M). The 1st harmonic is nearly at 8 Hz and the subsequent harmonics are separated by a frequency of 6 Hz. This was first estimated by W.O. Schumann (1952) and was detected experimentally by Balser and Wagner (1960). They detected the fundamental SR frequency as 7.8 Hz instead of theoretically predicted value 10 Hz. This is due to non perfect conductivity of the lower ionosphere. A detailed investigation of SR field considering different conductivity profile has been studied in a number of papers (Sentman 1996; Mushtak and William 2002 and references therein).

The global lightning activity which is the principal excitation source of SR is concentrated mostly in the tropical land mass particularly in three regions Africa (strongest one), South America and South-East Asia (Belyaev et al., 1999). Cloud to ground lightning discharges of global averages 100/s, with peak currents of the order of 20-30 kA of strokes of average lengths of 3 to 5 km, are sufficient to excite the Earth-ionosphere cavity and hence the observed Schumann resonances. From the intensity of SR even at a single station, the lightning source and its strength can be predicted. This can give the information of both diurnal as well as seasonal variation of lightning activity (Fullekrug and Fraser Smith, 1997). The continental lightning in mid and tropical latitude are found to be related to surface temperature variations. Hence monitoring of SR can be regarded as a tropical thermometer (William, 1992).

Recently, the influence of terminator effect (TE) on SR parameter has also been given much importance (Pechony et. al, 2007, Satori et. al 2007). The structure of the observed diurnal and seasonal variations of SR fields, enhancement of amplitude during day time with significant variations around sunrise and sunset in many records, give rise to the hypothesis that SR amplitude records are significantly influenced by ionosphere day-night asymmetry (Pechony et al; 2007). The line marking the transition between day and night is named 'day/night terminator', or simply the 'terminator', and the transition has a profound effect on the propagation of ELF wave. During the Sunrise and Sunset the electron concentration of the lower layers of the ionosphere changes very much and this has greater influence on ELF propagation (Bracewell and Brain, 1952). The non uniformity caused by day night change of conductivity profile has the influence on SR parameters. Depending on the position of the observational site, the terminator effect can be distinguished from the proximity effect of lightning source. Observationally, steep increase/decrease of SR amplitude during local Sunrise/Sunset time has been seen (Melinkov et. al 2004, Ondraskova 2007).

In high and mid latitude regions detailed studies of diurnal and seasonal variation of SR parameters have been studied (Price et. al, 2004; William 1992 and references therein). However, not much investigation has been done near Indian sector which itself is in the strong thunderstorm active region. In this paper we use searchcoil magnetometer data in order to study the diurnal variation of SR intensity in X, Y component and the TE observed in the Indian stations. We will also try to demonstrate how TE can be masked by strong lightning effect, especially by dominating features of diurnal pattern of SR intensity.

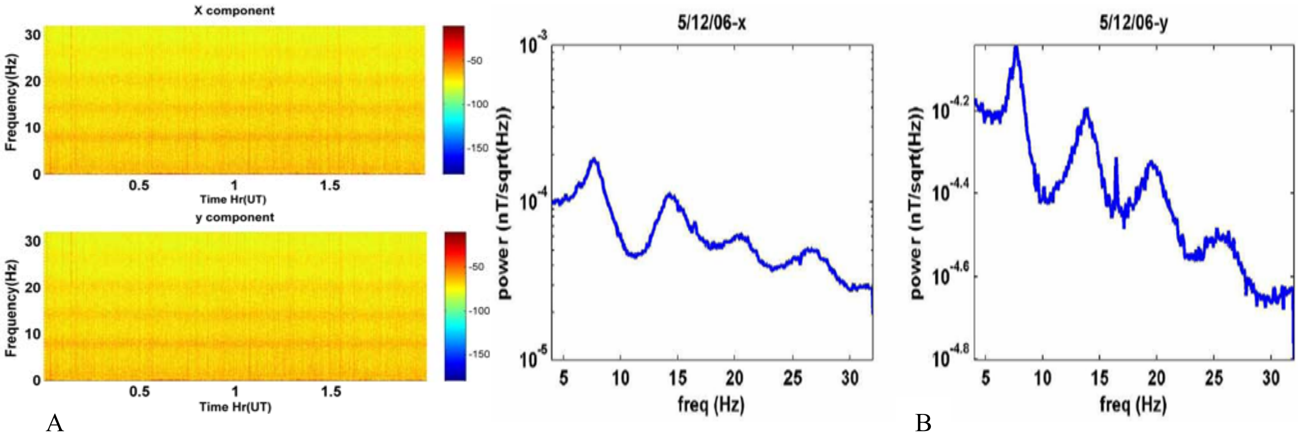

Fig. 1. (A) Dynamic spectrum obtained from search coil magnetic data at Shillong showing typically four harmonics of Schumann resonance – the upper panel shows North-East (X) component and the lower panel shows East-West (Y) component. Part (B) shows static spectra depicting four harmonics on 5th December, 2006 (0.0 - 2.0 UT)

2. Data and Analysis Technique

The observational sites Shillong (geographic co-ordinate lat 25° 34', long 91° 53', declination -0.474°) is located in the north-eastern part of India. Though the station is at remote place, the data are not free from the disturbance of powerful electric equipment, acoustic noise, movement by nearby magnetic material (vehicle etc) and other man made noises. Nevertheless, with the improved analysis technique, it was possible to study the characteristics of particular SR harmonics. The data is sampled at 64 Hz and the frequency response of the instrument is flat in the range 1 Hz-30 Hz.

First, we perform the spectral analysis on the data in order to check the presence of SR harmonics. The sampling rate (64 Hz) of the data and flat frequency response of the instrument (1-30 Hz) facilitates the way for SR to be observed up to fourth harmonic in the computed power spectra. In this paper we compute the static spectra as well as dynamic spectra of the data under investigation. The static spectrum gives the relative dominance of frequencies in the whole data set i.e. spectral density as a function of frequency; where as the dynamic spectrum shows the colour-coded power as a function of frequency at different time. The dynamic spectra were prepared taking Hamming window of 512 points (8 seconds) with sliding half the window size. The static spectra were prepared using Welch spectral technique which estimates the PSD of the input signal vector using Welch's averaged modified periodogram method of spectral estimation

The amplitude and phase of a particular SR harmonic are computed using complex demodulation technique. The procedure involves two steps. Firstly, a frequency band of interest (centred around the SR harmonic frequency Ω) is chosen for a time series and is shifted to zero frequency by multiplying the time series by the complex function exp $(-i \Omega t)$. In the second step, this new series is low pass filtered to produce a demodulated time series. This technique is easy to use and presents a high degree of resolution for non-stationary data (Webb 1979).

Here, we have studied diurnal pattern of amplitude variation of first SR harmonic averaged over three months (i.e. Nov 2006, Dec 2006 and Jan 2007). In order to apply complex demodulation technique, the central frequency Ω is chosen to be 7.6 Hz and the signal is low passed at 0.7 Hz after multiplying with exp $(-i \Omega t)$. The resulting output is used to compute the amplitude and phase variation of the first SR harmonic as a function of time.

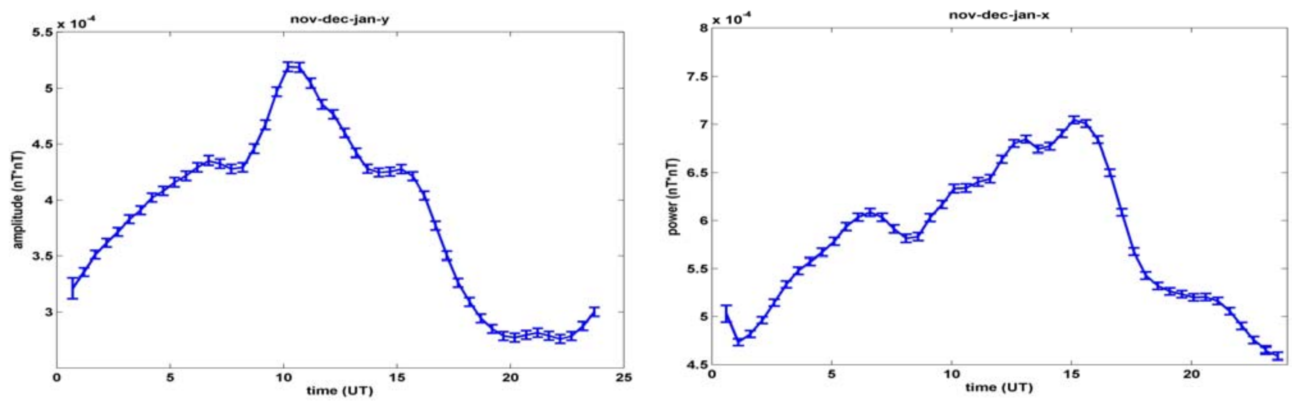

Fig. 2. Diurnal pattern of SR intensity averaged over three months (Nov. 2006, Dec. 2006 and Jan. 2007). The left panel corresponds to East-West component; where as the right panel corresponds to North- South component. Both the components show two common peaks at ~7 UT and ~20 UT corresponding to SE-Asia and South America, but the strongest peak corresponding to Africa is broader in N-S (X) component as compared to E-W (Y) component.

3. Results and Discussion

In Fig. 1, (A) shows the dynamic spectra and (B) shows the static spectra of the signal obtained at Shillong on 5th Dec 2006 from two hours data (0.0 – 2.0 UT). In part (A) upper and lower panels represent respectively N-S and E-W components, where as in part (B) of Fig. 1 corresponding static spectra are shown in left and right panels respectively. In both the static as well as the dynamic spectra, SR frequencies (enhanced power) up to 4th harmonic are seen at around 8, 14, 20, 26 Hz. The spikes seen in the static spectra are the sporadic noise caused by the stray electromagnetic signals. In both dynamic as well as static spectra the power decreases from the first harmonic to fourth harmonic. The amplitude of different SR harmonics at a particular observational site depends on the nodal structure of SR standing wave. In some sites the second harmonic may have more power than the first harmonic. Moreover, the damping gradually increases with the increase of harmonic number. That is why in general, power in the first harmonic is higher than other harmonics.

Fig. 2 shows the average amplitude variation pattern for three months viz. Nov 2006, Dec 2006 and Jan 2007. As the source receiver geometry and the direction of propagation of the ELF waves for X and Y component are different, pattern of amplitude variation is also quite different for these components. In case of magnetic field variation, amplitude should be the maximum if the source direction is orthogonal to the axis of the measuring coil. The diurnal variation of the amplitude for x component shows three distinct peaks- one at nearly 7 UT, one at nearly 15 UT (broad and largest) and another on 20 UT (smallest). These can be interpreted as peaks corresponding to the major thunderstorm activity sites i.e. South-east Asia, Africa and South America (William and Satori, 2004). The diurnal variation of the amplitude for Y component also shows three distinct peaks- one at nearly 7 UT, one at nearly 11 UT (strongest) and one nearly at 20 UT. This diurnal variation of amplitude is predominantly determined by the source receiver geometry. Among all the thunderstorm active regions large portion of the African continent is more towards orthogonality with respect to N-S coil as compared to E-W coil and hence the amplitude of Africa is the wider and stronger in X component as compared to that in the Y component. The whole African continent has noon time nearly over a period of 4 hours. There are some portion of the African continent at the noon time is 10-11 UT from where the propagation of ELF waves is nearly orthogonal to E-W direction, so the corresponding sharp peak is seen in Y component. For rest of the local noons of African continent (14-17 UT) the ELF waves show comparatively more response in the N-S component (because of the angular distance from the source and receiver). The ELF waves coming from the other two regions have components in both the N-S and E-W direction. So the contribution from these two regions are seen in both X and Y components. But the amplitude in the N-S is the dominant one.

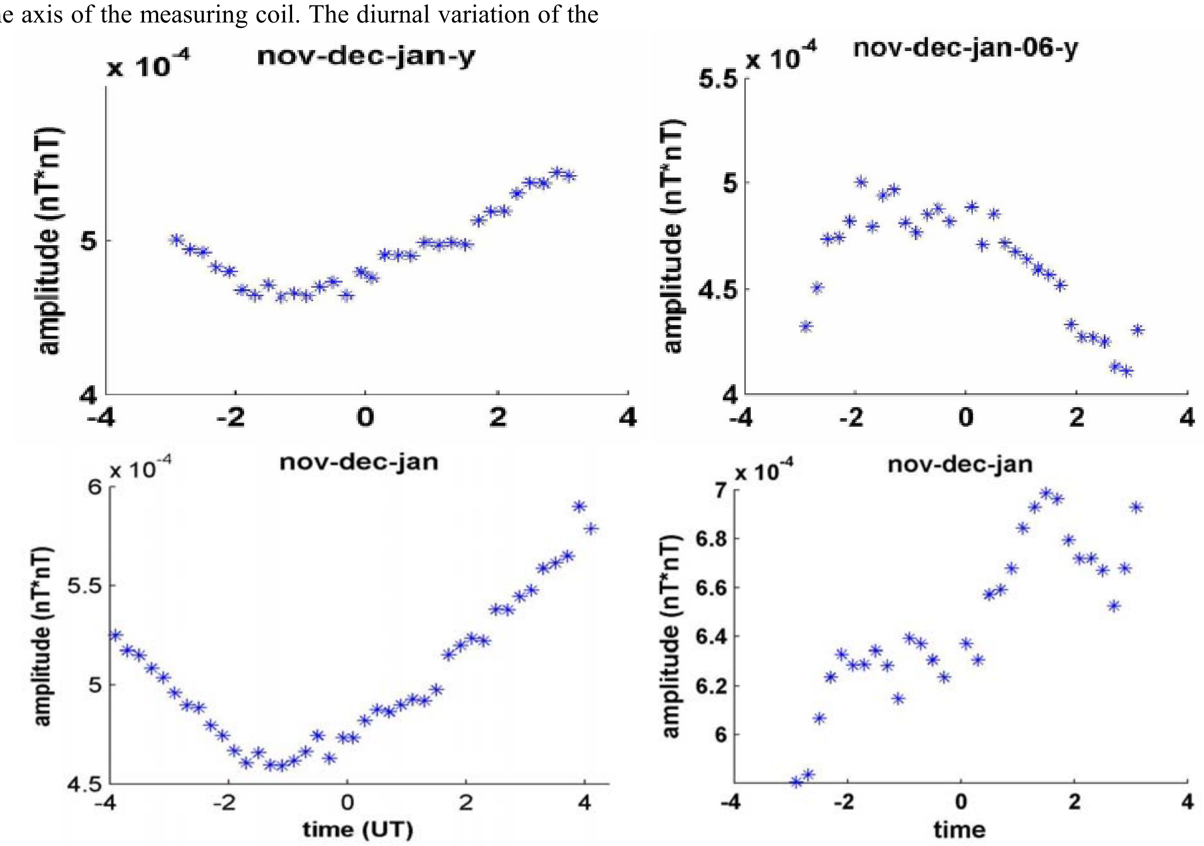

Fig. 3. The lower and upper panels corresponds to NS and EW components respectively, whereas left and right panel respectively correspond to sunrise and sunset time.

The terminator effect has been depicted in Fig. 3 showing the average amplitude for three months (Nov 2006, Dec 2006 and Jan 2007) for the first SR harmonic. The lower panel corresponds to the N-S (X) component and upper panel corresponds to E-W (Y) component, where as the left panel shows the sunrise effect and right panel shows the sunset effect. In all the plots the local Sunrise or Sunset time is taken as the terminator line (0.0 hours) and the amplitude three hours before and three hours after the terminator line are shown. Both the components (cf. left panel of Fig. 3) show the enhancement of the amplitude across the TE line. We observe a positive gradient in the amplitude in N-S and E-W components during sunrise time. Though it falls on the ascending phase of SE-Asian peak, the peaking up of the amplitude around 1 hr earlier suggests the impact of sunrise (ionospheric) effect.

The observation does not show the expected decrease in SR Intensity in N-S (X) component during sunset because local sunset time (11.0 UT) falls in the ascending phase of African peak of the diurnal N-S pattern. At this time the regions of African continent from where the ELF waves come affect mostly the X component. So it can be said that for X component, the TE during sunset time is totally masked by the thunderstorm effect. But in Y component the TE is observed during sunset time [cf. The right upper panel of Fig. 3]. The differences in the behaviour of the SR characteristic at the two terminators are also connected with difference in lateral ionosphere gradients in the morning and the evening terminators.

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