Review Article

IJCRR
Section: Technology
Sci. Journal
Impact Factor
4.016
ICV: 71.54

Schumann Resonance Mode Variation during Seismic Activity: A Review

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ABSTRACT

Seismic activity and thunderstorm centers have strong relation because of which fourth mode (26Hz) of Schumann Resonance (SR) is varying. SR has numbers of resonance frequencies like first mode (8 Hz), second mode (14 Hz), third mode (20 Hz) and fourth mode (26 Hz). The variation of 4th mode of SR is taken into account due to the seismic effect. Characteristics of ionosphere changes on surface during & aftershock the main shock (https://www.britannica.com/science/aftershock-geology). The effective height of the ionosphere lower boundary is reduced to a few tens of kilometer. The lower ionosphere & mesosphere is modified by the seismic source detection of modification in higher frequency band. The Schumann Resonance signal is supported by electromagnetic radiation from the global thunderstorms & the anomaly in SR fourth mode frequency i.e. the shifting of frequency due to lowering of Ionosphere height is accumulated in this paper.

Key Words: Schumann resonance, Earthquake, ELF, Fourth mode SR, Ionosphere, Thunderstorm

INTRODUCTION

Seismic Activity

The displacement of two or more plates causes faults and resulting shaking in the earth surface and energy released in the form of earthquake. The volcanic or magmatic activity may also be associated with ground shaking. If any of two blocks of the earth suddenly slip past one another then it happens. The fig.1 shows surface slip due to which fault plane created. In the location where the earthquake starts below earth's surface is called the hypocenter, and the location which directly above on surface of the earth is called the epicenter.

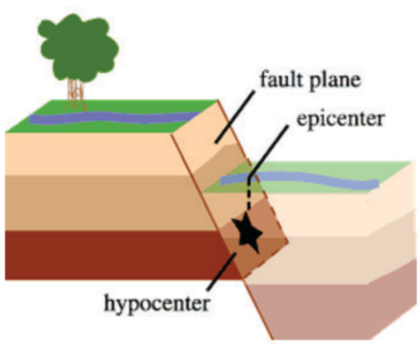

Figure 1: Basic nomenclature of earthquake.

Sometimes some smaller earthquakes are happening in the same place where the larger earthquake follows that kind of earthquake has foreshocks. During the strong seismo-ionospheric coupling processes in the earthquake preparation zone, underground gas discharges carry submicron aerosols with them which enhance the intensity of electric field at the near ground due to the drop in air conductivity created by aerosols. Seismo-electromagnetic emissions have been observed at low frequency bands in the seismically active zones prior to the incidence of any large earthquake (Nagao et al., 2002) which are different from lightning induced and technogenic emissions. On the event of strong earthquake, the near ground of the atmospheric layer becomes ionized and generates electric field which introduces particle acceleration thereby exciting local plasma instabilities.

The tectonic plates are moving continually and get stuck at the edges by the friction. Earthquake releases energy in the form of waves that travel through the earth's crust when the stress on the edge overcomes the friction. Due to the sudden release of energy in the Earth's crust it creates earthquakes.

Schumann resonances (SR) Phenomena

The extremely low frequency (ELF) portion of the Earth's electromagnetic field spectrum which set of spectrum peaks are called Schumann Resonances (SR) (Fig. 4). Schumann

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ISSN: 2231-2196 (Print) **ISSN:** 0975-5241 (Online) **DOI:** 10.7324/IJCRR.2017.9147

Received: 02.05.2017 **Revised:** 24.05.2017 **Accepted:** 18.06.2017

resonances are global electromagnetic resonances is excited by lightning discharges in the cavity formed by the earth-surface and the ionosphere (as shown in fig. 3). The space between surface of the Earth and the conductive ionosphere acts as a closed waveguide for Schumann resonances occur. This waveguide to act as a resonant cavity for electromagnetic waves in the ELF band which result the limited dimensions of the Earth cause. The Schumann Resonances are quasi standing wave electromagnetic waves which exist in this cavity. The several frequencies between 6 and 50 cycles per second; specifically 7.8,14, 20, 26, 33, 39 and 45 Hz, as daily variation of about +/- 0.5 Hz for occur by them. The Earth's ionosphere changes in response to the 11-year cycle of solar activity which is some change due to solar sunspot cycle (fig.2) . They are most easily seen between 2000 and 2200 UT.

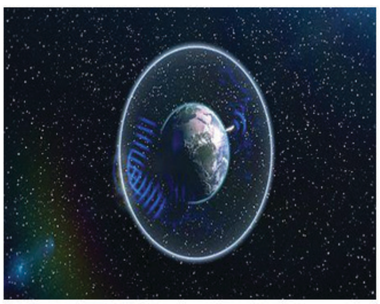

Figure 2: Earth's electromagnetic field spectrum [https://www.elpensante.com/el-alma-de-la-tierra-la-resonancia-schumann-y-los-vinculos-del-hombre-con-la-naturaleza/]

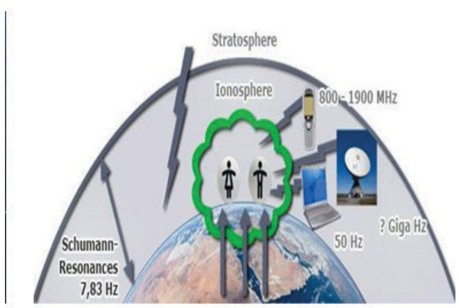

Figure 3: Schumann Resonance in Earth-Ionospherecavity. [http://sedonanomalies.weebly.com/schumann-resonance.html]

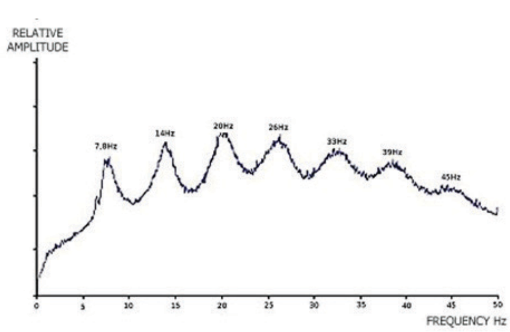

Figure 4: Different modes of SR signal. [http://www.vlf.it/poggi1/schumann.html]

Responsible Parameters for Schumann Resonance

Global lightning was used to monitor global lightning activity about 2000 thunderstorms around the globe given from Schumann resonance studies. The background Schumann resonance signal is directly linked from producing ~50 lightning events per second, thunderstorms. Schumann resonance records are a complex problem to the spatial lightning distribution: the lightning intensity estimate in order .The distance from lightning sources and the wave propagation between the source and the observer both are the necessary account of its . The cavity is spherically symmetric assumes of this technique. Therefore believed to affect the resonance that does not include known cavity asymmetries propagation properties of electromagnetic waves in the system.

Diurnal variations meant by the background Schumann resonance power spectrum. Global lightning activity and the state of the Earth–ionosphere cavity between the source region and the observer both are the properties of characteristic Schumann resonance diurnal record reflects. The vertical electric field is independent of the direction of the source relative to the observer which is a measure of global lightning.

The Schumann resonances transients (Q bursts) and the transient luminous events (TLEs) both are related. In 1995 Boccippio et al that sprites, the most common TLE, region of a thunderstorm system to the produced by positive cloud-to-ground lightning occurring in the strait which are accompanied by Q-burst in the Schumann resonances band. The occurrences of sprites are revealing recent observations .Q bursts are highly correlated and Schumann resonances data can possibly be used to estimate the global occurrence rate of sprites.

The global temperature and the Schumann resonances are also monitored. There are increases nonlinearly with temperature between Schumann resonance and temperature is lightning flash rate. The nonlinearity of the lightning-to-temperature relation provides a natural amplifier of the temperature changes .It makes Schumann resonance a sensitive "thermometer". The global mean temperature in the low latitude range for only Hew component (correlation coefficient about -0.9) which correlate well Extracted semiannual variations of the SR intensity. Two horizontal magnetic components are negative relation with the global thunderstorm activity. A significant correlation between the middle latitude temperature and the annual component of SR energy until the semi-annual component of the SR energy and low latitude temperature both are also significant correlation

Tropospheric water vapor is a element direct effects as a greenhouse gas. global lightning activity and upper-tropospheric water-vapour variability both are closely linked, upper-tropospheric water-vapour changes can be inferred from records of global lightning activity for suggesting of a single location on the Earth's surface observations to any obtain. The thunderstorms transport large amounts of water vapour into the upper troposphere and thereby dominate the variations of global upper-tropospheric water vapour while producing most of the lightning on Earth that correlation reflects the fact of continental deep-convective. Observed easily, that global lightning induces Schumann resonances, an electromagnetic phenomenon are in the atmosphere

Review of Literature

Third mode to fourth mode of Schumann Resonance is taken into consideration because of shifting of frequency in time frame of large earthquake. Earth's surface & lower ionosphere made a wave guide. The ionization occurred at about 50 Km above by solar radiation and cosmic rays. Which ionization is completely different at day time from night time [Plok 1982].The conductivity of SR signal changes as the lower boundary changes. Here the lower band of the ionosphere acts as the earth-ionosphere cavity controller. The observed variations were explained by the variations in the source-receiver geometry [Balser and Wagner, 1960], and it was concluded that no particular systematic changes of the ionosphere are needed to explain these variations [Madden and Thompson, 1965].

SR Anomaly during Large Earthquake:

The two waves, direct wave generated from the active thunderstorm center and scattered wave from epicentral region are interfere which results the frequency shifting of higher mode of SR. In this wave the magnetic field component propagating in north-south meridian plane [Haykawa et al., 2005].In some model it was assumed that the conductivity increased due to Total Electron Content (TEC) enhancement in epicentral region. During thunderstroms electromagnetic wave generated by the excitation of lightning [S.S De et al., 2008]. Some relation also found the power of the 1st mode of SR and the global temperature variations. Aerosol particles moves randomly in the vicinity of the earthquake zone and as because of the connective nature of atmosphere there is a directional flow is also there which causes the atmospheric temperature changes. The movement of electromagnetic wave also affected within the earth-ionosphere cavity which in turn changes in SR waves.

The Stratton-chu integral equation technique when constructing the electromagnetic field is non-uniform earth ionosphere cavity [Nickolaenko el. al.2002].The vertical electric field in the earth ionosphere cavity with a localized non- uniform is a combination of direct & scattered waves:

$$Er = E1 + E2$$

E1 is the primary wave, the 2nd wave E2 assuming that the seismic activity locally modifies the ionosphere height.

For Taiwan earthquake the records were done at Nakatsugawa observatory where narrowband transient waves observed in SR fourth mode [Ohta et. al.,2001,2003]. The narrow band continuous signal in the horizontal magnetic field component increases the fourth mode Schumann Resonance by two times before and after the main shock [Nicolaenko et al.,2005]. The large earthquake (M=7.8) occurred in Taiwan on 26 December 2006, the ELF signals were recorded at Moshiri (44.29ºN, 142.21ºE) in Hokkaido, Japan, which indicates the anomalous behavior in the Schumann resonance mode, ELF radio wave caused by the lower ionospheric depression around the earthquake epicenter [Hayakawa et al.,2008].

The non-uniformity of the scattered waves is due to the inhomogeneity of the ground surface, irregular conductivity of atmosphere. An isotropic nature of ionosphere is considered for the direct wave [Molchanov et al., 1995].The spatial distribution of ULF magnetic and electric field within the scattered wave are responsible for intensity enhancement of SR and this spatial distribution is effective for 100-200Km horizontal distances [Molchanov et al., 1995] i.e. the source and observatory distance should be within the range of spatial distribution for observing the changes in SR.

DISCUSSION

The shifting of frequencies in fourth mode (26 Hz) and first mode (8Hz) of SR are highlighted in this paper. Two to three days before the main shock the height of the lower ionosphere reduced by near about 20Km which turns into some modification in the ELF electric field. This modification may cause the shift in peak frequencies by certain small percent [Nickolaenko and Hayakawa, 2002]. So SR is considered to a review of lower ionosphere [Hayakawa, 2007; Molchanov and Hayakawa, 2008]. East-West component (B_{EW}) and North-South component (B_{NS}) of the horizontal electrified increases and the vertical component E_z also increased in fourth mode of Schumann resonance. The main responsible is B_{EW} component compare to B_{NS} component.

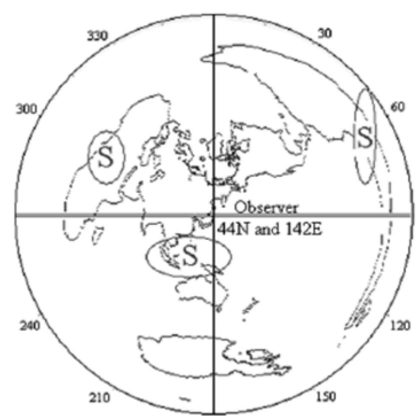

Figure 5: Global Map for indicating the Lightning centers (Hayakawa et al. 2008).

Three global lightning centers situated in America, Africa, and Asia as shown in fig. 5 indicated by 'S'. These three centers are responsible for contributing the SR signals by the generated lightning strokes at around Universal Time (8±1) h for Asia, (15±1)h for Africa and (21±1)h for America. The observatory and the epicenter of the earthquake are different and so the radio signals (ELF) reached to the observer in different direction in a day [Nickolaenko and Hayakawa, 2002]. In -Moshiri (Japan) earthquake in Hokkaido, on 26 December 2006, the modification due to the lowering of ionosphere occurred in the interval of 21:00 UT±1 h which was contributed by the American thunderstorm center and irregular behavior observed on 23 December 2006.

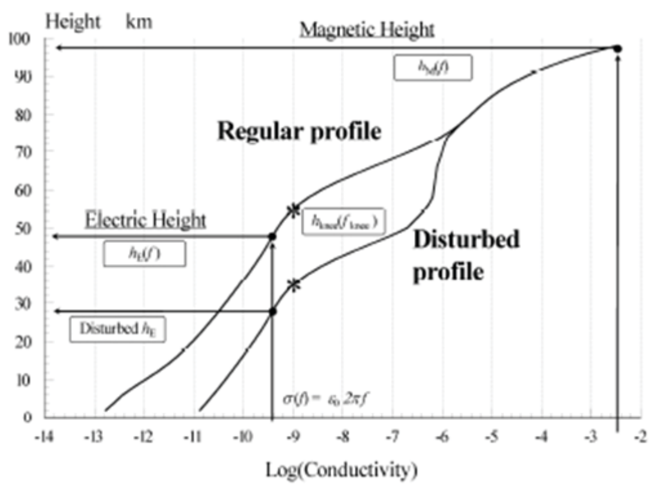

Figure 6: Nature of Ionospheric profile lowering compared to fair-weather profile (Hayakawa et al., 2008).

It was observed (fig. 6) the ELF signal perturbed due to the lowering of the lower ionosphere height around the epicentral region of earthquake. In case of Taiwan earthquake in September 1999 the Q-factor for 4th mode of SR becomes nearly 10 which is approximately double the natural SR value because of introduction of some train noise [Nickolaenko and Hayakawa 2002]. In this case it was strongly established that this anomaly as because of thunderstorm center at America. From the study of behavior of several earthquake mainly in Japan and Taiwan, it is observed that the fourth mode Schumann Resonance shows the anomaly for the larger earthquake having magnitude of greater than or equal to 6.

CONCLUSION

The radio ELF signal generated from the thunderstorm centers known as direct wave are enter in to the earth-ionosphere cavity and propagate within the cavity but because of the depression of lower ionosphere the propagation takes place differently. Scattered wave, generated from the disturbed region above the earthquake epicenter has different path length with respect to direct wave. These two waves make interference in SR modes which is responsible for shifting of Schumann Resonance mode by nearly 1Hz almost 2-3 days before the large shock (Hayakawa et al., 2008). Variation of Schumann Resonance also depends on source and observer distance. (https://www.revolvy.com/topic/Schumann%20resonance&item_type=to pic). An anomaly in the SR (Fourth Mode) signals depends on the magnitude of earthquake and the distance between observatory and earthquake epicenter. For larger earthquake, SR frequency shift is higher than the small (not less than M=6) earthquake. Convective nature of the atmosphere changes the aerosol movement and the temporal changes may occur which contribute to the SR modes which may also be taken into consideration.

ACKNOWLEDGEMENTS

The authors acknowledge with thanks the support from Narula Institute of Technology, Agarpara, Kolkata, India for encouraging in research work and giving scope in this regard. We also thankful to the department of Electronics and Communication Engineering of Narula Institute of Technology, for carrying out the study.

Authors acknowledge the immense help received from the scholars whose articles are cited and included in references of this manuscript. The authors are also grateful to authors / editors / publishers of all those articles, journals and books from where the literature for this article has been reviewed and discussed.

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