ANOMALOUS BEHAVIOR OF SCHUMANN RESONANCE, POSSIBLY ASSOCIATED WITH TAIWAN EARTHQUAKES

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Abstract: In order to measure the direct wave near the ground surface of the epicenter to detect any precursory phenomena, especially ULF/ELF frequency range is considered to be very promising because the propagation loss is very low in this frequency. We have carried out our continuous observation of three magnetic components in the frequency range below 50Hz at Nakatsugawa (Geographic lat. 35° 25 ' N, long. 137° 33' E, Geomagnetic lat. 25° 05' N) in Gifu Prefecture near the foot of Mt. Ena in Japan, where the electromagnetic environment is good. In this frequency band, we have tried to observe the fluctuation of ionosphere by means of Schumann resonance. We will report on the abnormal behavior of Schumann resonance and its relationship to the Taiwan earthquakes.

Keywords : Precursor of earthquake, Direction finding of ELF wave, Schumann resonance

1. Introduction

The Schumann resonance in the ELF range is a phenomenon occurring in the cavity formed by the perfect conducting earth and ionosphere. And the wave source is a lightning discharge [1] [2] [3]. Resonance frequency consists of the fundamental wave at 8Hz (the first mode; Sch1) and the higher harmonics (second mode wave at 14Hz; Sch2, the third mode wave at 20Hz; Sch3, the fourth mode wave at 26Hz; Sch4). Generally the frequency of the resonance depends on the propagation condition (land / sea, day / night), and also it is assumed that the intensity of each mode depends on the distance from the lightning discharge to an observation point. We have carried out the observation of ELF electromagnetic waves as a study of earthquake prediction phenomena at the observatory of Nakatsugawa, Gifu in Japan [4]. In this paper we will report on the precursor of earthquakes and analysis results on the anomalous excitation of Schumann resonance observed at Nakatsugawa

2. Method of analyses

Fig. 1 shows our observation system [4]. In Fig. 1, three magnetic field components (Bx, By, Bz) are detected with each induction coil antenna (The perm alloy of 1.2m length with 100,000 turns of the copper wire) and are fed to amplifier (66dB) including LPF of 10Hz and 30Hz. After that the signal of each component is digitized with sampling time of 10ms by date recording device (DL-708 YOKOGAWA ELECTRIC). Observation of ELF is stopped only five minutes for saving data to Hard Disk every six hours. So four files (from 0:00 to 5:55; file 0, from 6:00 to 11:55; file 1, from 12:00 to 17:55; file 2, and from 18:00 to 23:55; file3) are made in a day. Electromagnetic signal is analyzed by FFT method with data length of 1024. By this method, the amplitude ratio and phase difference between the three magnetic components are given with the frequency resolution 0.098Hz and time resolution 10.24s. The time of the system is controlled by GPS, and time marker is also recorded. These data are regularly collected and we change a Hard Disk and continue our observation.

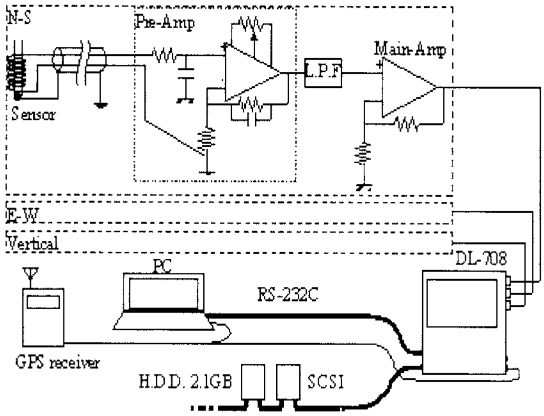

Fig. 1. The observation system of electromagnetic wave in ELF.

3. Schumann resonance and Taiwan earthquakes

Taiwan earthquake with magnitude 7.6 occurred at Chi-Chi in Taiwan at 2:47 (All the time is given in Japanese Standard Time) on September 21 in 1999. We have observed an excitation of impulsive noise and the background noise of ELF band below 50Hz before the earthquake at Nakatsugawa observatory, and estimated by using the goniometer direction finding that this background electromagnetic noise occurred in Taiwan. And we found that the outbreak of the noises occurred several hours before the main shock [4]. Thus, using these observational data, we will investigate the relationship between abnormal occurrence of Schumann resonance and earthquakes.

Fig. 2 is a sonogram of the magnetic field EW (Bx) during the period from 6:00 to 11:55 (file 1) on September 15 in 1999, analyzed by FFT. The horizontal axis shows the time (from 6:00 to 11:55, time resolution 10.24s), and the vertical axis shows the frequency (from 0Hz to 50Hz, frequency resolution 0.098Hz) and the intensity is shown in colors.

Abnormal propagation of Schumann resonance is clearly shown in Fig. 2, only Sch4 is extremely strongly excited even though the signals from Sch1 to Sch3 are buried among the background noise. Normally Schumann resonance of Sch1 and Sch2 are observed, but Sch4 is not observed because of the weak intensity buried in the background noises at Nakatsugawa. However, Fig. 2 shows an extremely special example. Unfortunately our setting of the equipment was not fully enough at this time, because aliasing noise symmetry with 25Hz can be seen in Fig. 2. Fig. 2 is also characterized by impulsive noises caused by many lighting discharges in summer at our observation site. There is no relation between the impulsive noises in Fig. 2 and excitation of Schumann resonance, so that the impulsive noises in Fig. 2 are the thunder activity near the observatory.

The measurement of direction finding method in ELF such as Schumann resonance is not established, but we will try goniometer direction finding here. ELF waves in the Schumann resonance region are TEM mode of propagation, so that the goniometer method is effective.

Center frequency and arrival direction of Sch4 are shown in Table 1.

Table 1 Center frequency and arrival direction of Sch4 (magnetic field EW).

Magnetic field EW (Bx)	Sch4
Center frequency	25.19Hz
Center angle of arrival direction	252.5°

Fig. 3 shows the condition that Schumann resonance is excited by impulsive noises (probably, these are so-called Q bursts). Sonogram of Schumann resonance, Sch4 in Fig. 3, shows the magnetic field (EW (Bx)) of file 0 on September 15, six hours before Fig.2. Fig. 3 also shows that Sch4 might be related to these impulsive noises with particular arrival direction, which have caused an excitation of Schumann resonance. Peak value of arrival direction of impulsive noises from 0Hz to 50Hz shows 235° by the goniometer method. In other words, impulsive noises are found to come to Nakatsugawa with the angle of 235°. This fact shows that impulsive noises disturbed the ionosphere near the lightning, which caused the excitation of Schumann resonance, and reflected the wave of Schumann resonance in all directions. The most important point is that we had the Taiwan earthquake with M7.6 after 6 days of the abnormal excitation of Schumann resonance. And if we know the direction of lightning discharges exciting the Schumann resonance, we will be able to locate the area of an earthquake before the main shock.

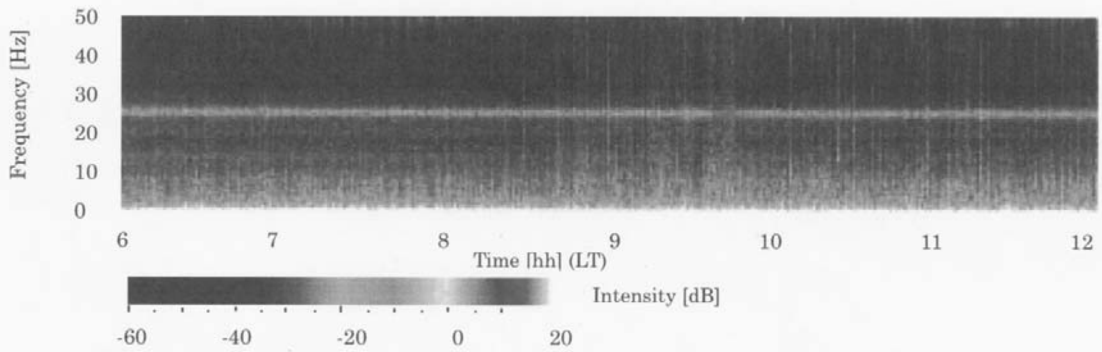

Fig. 2. Sonogram (magnetic field EW (Bx)) of file 1 on September 15 in 1999.

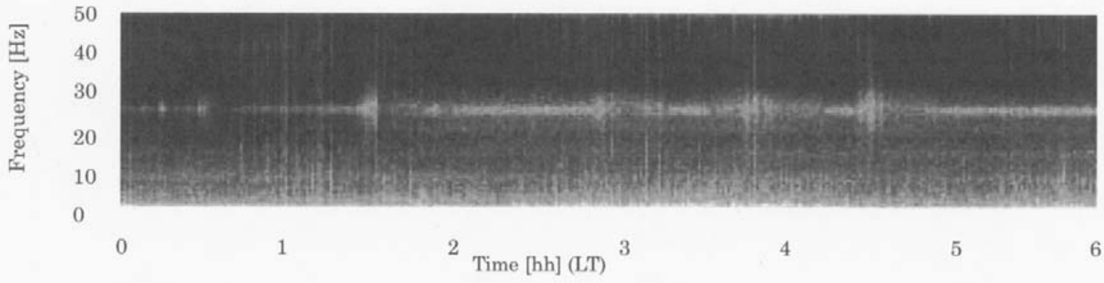

Fig. 3. Sonogram (magnetic field EW (Bx)) of file 0 on September 15 in 1999.

As for the Schumann resonance, the fundamental wave (Sch1) at 8Hz, second harmonic at 14Hz (Sch2), third harmonic at 20Hz (Sch3), and the fourth harmonics of 26Hz (Sch4) are generally observed. Also, the fundamental wave is usually the strongest, and the higher harmonic resonances are hardly observed because they are easy to be buried in the background noise. It is a rare case that higher harmonics are received with high intensity, and generally the intensity of Schumann resonance changes corresponding to the daily fluctuations of propagation path. However, as for the excitation of Schumann resonance that began in file 0 on September 15, Sch4 continues to be at the maximum intensity to file 3 on September 19. In this way, extremely and powerfully excitation of Sch4 was found only on September in 1999. Fig. 4 shows the average intensity of Sch4 of every files from September 1 to 30 in 1999.

So the center frequency of Schumann resonance for Sch4 is always changing that we cannot analyze the single frequency for a long term. We will analyze here the intensity with a range from 20.02Hz to 34.96Hz.

An extremely grow-up of Sch4 is shown from September 15 to 16 in Fig. 4. At 2:47 on September 21 (6 days later), an earthquake of M7.6 (depth 30km) and its aftershocks of M6.0 (84km) at 2:57, and M6.1 (90km) at 3:11 took place in Taiwan. And also an aftershock M6.4 (30km) was observed at 9:15 on September 22 [6]. Additionally, the rise up of Sch4, not so strong as the event on September 15 and 16, is observed for a long term from September 23 to 25. And an aftershock of M6.3 (40km) was observed once again near the same point of main shock at 8:53 on September 26. So, we cannot conclude whether the rise up of Schumann resonance for a long term from September23 to 25 is the elect of the main shock on September 21 and another aftershock, nor a precursory phenomenon of the earthquake on September 26.

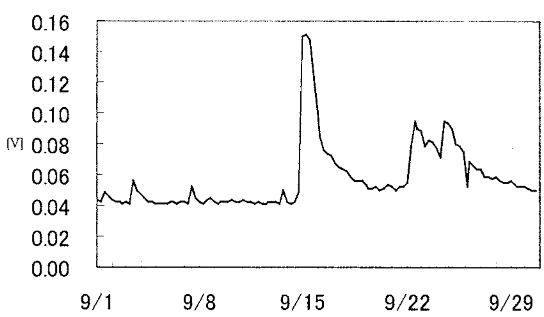

Fig. 4. The drift of the intensity of Sch4 in September.

4. Conclusion

Various techniques on short-term earthquake prediction are reported because precursory phenomena with electromagnetic waves are flourishingly studied [7] [8] [9]. We have observed the direct electromagnetic ELF wave occurred from the epicenter and scattering of VLF radio waves at the ionosphere that is considered to be perturbed by some energy from the epicenter. These different methods, direct wave or reflected wave, and ELF band or VLF band require many efforts for observation and analyses. So we have developed a new method for precursory phenomena to observe the direct wave below 50Hz, and the Schumann resonance.

We have reported here not only the direct wave below 50Hz, but also Schumann resonance wave reflected from the ionosphere. As a result, we have found extremely interesting relations between the excitation of abnormal Schumann resonance and earthquakes. And we conclude that these precursory phenomena occur several days before the main shock. We will try the statistical analyses on the basis of a long-term observation.

Acknowledgement

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