Co-seismic VHF Emissions Associated with Earthquakes

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1. Introduction

Many observations have been made in order to clarify the relationship between electromagnetic (EM) phenomena and earthquake (EQ) activities [1]. We have been observing EM waves associated with earthquakes by PLL type synthesized FM tuners from 76MHz to 90MHz in very high frequency (VHF) band [2]. This frequency band is strictly administrated for FM broadcasting use in Japan and hardly influenced by artificial or urban noises compared with other lower frequency bands. On observing EM phenomena in FM broadcasting frequency band, an observation method that distinguishes seismic EM waves from FM broadcasting waves is required. Therefore, we have developed a novel dual frequency method in which the observation is made at two different frequencies of fn and fr [2]. We are now operating the observation systems at 15 sites in Japan in order to detect seismic EM phenomena. First of all, we are trying to detect co-seismic phenomena. Because, the phenomena are much easier to identify with certainty than pre-seismic ones, may contain useful information to study seismic EM phenomena. Some co-seismic phenomena have been reported in relatively lower frequency bands [3],[4],[5],[6]. During our observation, co-seismic VHF emissions have been detected on three earthquakes, Tottori-ken-seibu EQ in 2000, Geiyo EQ in 2001 and Ibaraki-ken-oki EQ in 2002. In this extended abstract, we describe the observation method and observation results of Geiyo EQ and Ibaraki-ken-oki EQ respectively. Co-seismic broadband EM emissions associated with the Geiyo EQ were detected by the observation system located at Hiroshima City University (HCU) 45 km from the epicenter [7]. The observed EM waves rose up to the peak level right after the EQ, then slowly returned to a normal level about three hours later. The maximum peak level of -98dBm was observed in the west direction that was not toward the epicenter. The peak levels of EM waves were detected at 15:28:20 (JST) after the occurrence time of the Geiyo EQ, at 15:27:54 (JST). Similar co-seismic broadband EM emissions associated with Ibaraki-ken-oki EQ were also detected by the observation system located at Ibaraki University 39 km from the epicenter. The observed EM waves were similarly fluctuated as Geiyo EQ in 2001. The maximum peak level of -102dBm was observed in the north direction not toward the epicenter. The peak levels of EM waves were detected at the observatory 20 seconds later of the occurrence time of the Ibaraki-ken-oki EQ. By referring to the observation of seismic waves, it was confirmed that the starting times of VHF emissions were corresponding to the seismic P-wave and S-wave arrival times, respectively.

2. Observation Method

We chose the FM broadcasting frequency channels (from 76MHz to 90MHz) in VHF band as our observation. Because, we are surrounded with a lot of EM waves such as broadcasting, communication use and a lot of artificial, manmade noises, which are higher intensity than that of seismic EM waves. This frequency band is assigned for FM broadcasting exclusive use in Japan, so it is well administered against other EM interferences. Therefore, EM wave observation on this frequency band is available less to be affected by artificial and urban noises compared with other lower frequency bands [8].
At the observation in the FM broadcasting frequency band, we have to realize an accurate observation method to identify seismic EM waves from FM broadcasting waves. So, we have developed the dual frequency method as shown in Fig.1. In our method, we set two different frequencies (fn and fr) for the observation channels [2].
The frequency of ‘fn’ is selected from 80.8MHz to 81.2MHz band, which frequencies are not assigned for any FM broadcasting use in Japan. So, these frequencies are vacant and are occasionally interfered by the 3rd order distortion of amateur radios in the 27 MHz citizen band in Japan.
The frequency of ‘fr’ is selected the channel of the minimum received level at the observatory from 76MHz to 90MHz band. The selected fr channel is not usually received at the observatory, because it is used at a remote FM radio station far from the EM observatory.
Then, there are three observation cases in the dual frequency method as follows.
Case 1: Fluctuation in only fn frequency; in this case, a received wave is considered as the 3rd order distortion of 27MHz amateur radio wave. It is confirmed that it is an amateur radio communication from the demodulated

signal of the receiver.

Case 2: Fluctuation in only fr frequency; in this case, a received wave is considered as an FM broadcasting wave reached from a remote FM station to the observatory. The FM radio station is easily identified by the demodulated signal of the receiver.

Case 3: Fluctuation in both fn and fr frequencies; in this case, a received signal is considered as a broadband EM wave. The demodulated signal indicates an FM noise sound.

Then, we can identify whether a received signal is artificial waves or a broadband EM wave by the dual frequency method. In our observation system, a synthesize FM tuner is adopted, and this tuner has a receiving bandwidth of 100kHz/3dB and a noise figure of 2dB. The limitation of measuring level is about -120dBm, so that the Galactic noise of -110dBm can be detected by the observation system. At the observatory, four FM antennas are installed on the roof toward east, west, south and north, respectively. Each of antenna is connected with two synthesize FM tuners to measure the EM levels of fn and fr channels respectively. All observation data are stored by the personal computer. The observation time is adjusted by the GPS clock every hours. We are now operating the systems with 120 FM tuners at 15 observatories in Japan.

3. Observation Results Associated with the Geiyo Earthquake in 2001

The Geiyo earthquake of Magnitude 6.4 was occurred at 15:27:54 (JST) on March 24, 2001. Fig. 2 depicts a map of the EM waves observatory, the seismic wave observatory and the epicenter of the Geiyo EQ. Hiroshima City University (HCU) for EM observation is about 45 km far away from the epicenter and the K-net Hiroshima observatory is about 38 km from the epicenter. Fig. 3 shows the time variations of detected EM waves at HCU observatory. A sharp rise is followed by a slower decline in each direction [7]. Both of the levels of fn and fr frequency channels were similarly fluctuated. The demodulated signal indicated an FM noise sound. Therefore, It is suggested that the detected EM waves are broadband. The detected levels slowly decreased and returned to the normal level about three hours later as well as the Tottori-ken-seibu EQ [2]. The peak levels detected in four directions are illustrated in Fig. 4. The maximum peak level of -98dBm was observed in the west direction. It suggests that the detected EM waves are not from the epicenter. Fig. 5 shows the more detail time variations of detected EM waves and seismic waves from 15:26 to 15:31, JST on March 24, 2001. The seismic variations were detected at Hiroshima K-net observatory and the EM waves were detected at HCU observatory with a sampling rate of 10 seconds. The seismic P-wave arrived at Hiroshima K-net observatory at 15:28:06. In EM wave variations, the solid line shows received levels of 80.9MHz (fn) and the doted line shows received levels of 84.6MHz (fr) in the west direction. The EM waves rose up at 15:28:10 and the maximum level of -98dBm was recorded at 15:28:20, after the occurrence time of the Geiyo EQ, 15:27:54. This result suggests that the detected EM wave rose up the peak level corresponding to the seismic wave arrival at the HCU.

4. Observation Results Associated with the Ibaraki-ken-oki Earthquake in 2002

The Ibaraki-ken-oki earthquake of Magnitude 5.5 was occurred at 22:44:38 (JST) on February 12, 2002. Fig. 6 depicts a map of the EM waves observatory, the seismic wave observatory and the epicenter of the Ibaraki-ken-oki EQ. The Ibaraki University for EM observation is about 39 km far away from the epicenter and the seismic wave K-net Hitachi observatory is also about 39 km from the epicenter. Co-seismic EM waves similarly detected at Ibaraki University observatory. Fig. 7 shows the peak levels in four directions. The peak level of –102dBm is detected in north direction not in the epicenter direction. Fig. 8 shows the more detail time variations of detected EM waves and seismic waves from 22:43 to 22:48, JST on February 22, 2002. The seismic waves were detected at Hitachi K-net observatory and the EM waves were detected at Ibaraki University observatory with sampling rate of 2 seconds. In EM wave variations, the solid line shows received levels of 80.9MHz (fn) and the doted line shows received levels of 77.8MHz (fr). The EM waves rose up at 22:44:48 corresponding to the seismic P-wave arrival time and at 22:44:54 to the seismic S-wave arrival time. The peak level of –102dBm is detected 22:44:58. By the observation with sampling rate of 2 seconds, it was confirmed that the starting times of VHF emissions corresponded to arrival times of seismic P-wave and S-wave, respectively.

5. Conclusions

We have been observing electromagnetic phenomena associated with earthquakes in VHF band since 1997. The observation systems with 120 FM tuners are now operating at 15 observatories in Japan. During the observation period, the systems have detected co-seismic EM phenomena in three earthquakes. This extended abstract has described the observation method and results associated with Geiyo EQ in 2001 and Ibaraki-ken-oki EQ in 2002.

The observation results are summarized as follows:

- A co-seismic EM phenomenon has been detected in VHF band.
- The detected EM waves have broadband spectra.
- The VHF emissions have been continued for about three hours, after the seismic wave.
- The detected peak level was not observed toward the epicenter.
- The starting times of VHF emissions corresponded to arrival times of seismic P- and S-wave, respectively.

References

[1] M. Hayakawa, (ed), "Atmospheric and Ionospheric Electromagnetic Phenomena Associated with Earthquakes", *Terra Science Publishing Company*, Tokyo, 1999.

[2] T. Yoshida and M. Nishi, "The Observation of Broadband Co-seismic Electromagnetic Waves in VHF Band", *2001 IEEE AP-S*, pp.184-187, July 8-13, in Boston, 2001.

[3] M.B. Gokhberg, V.A. Morgounov, T. Yoshino, I. Tomizawa, "Experimental Measurement of Electromagnetic Emissions Possibly Related to Earthquakes in Japan", , *J. Geophys. Res*, Vol. 87, No. B9, pp.7824-7828, 1982.

[4] N. Takeuchi, N. Chubachi and K. Narita, "Characteristics of Earth Potential Difference Generations by Seismic Wave", T. IEE, Vol. 116-C, No. 9, pp.1064-1069, 1996.

[5] Y. Fujinawa and K. Takahashi, "Electromagnetic Radiations Associated with Major Earthquakes", Phisics of the Earth and Planetary Interiors, 105. pp.249-259, 1998.

[6] T. Nagao, Y. Orihara, T. Yamaguchi, I. Takahashi, K. Hattori, Y. Noda, K. Sayanagi and S. Uyeda, "Co-seismic Geoelectric Potential Changes Observed in Japan", *Geophys. Res. Lett.*, 27, 1535-1538, 2000.

[7] T. Yoshida and M. Nishi, "Observation of Co-seismic Electromagnetic Phenomena in VHF Associated with the Tottori-ken Seibu Earthquake in 2000 and the Geiyo Earthquake in 2001", Zishin, Journal of the Seismological Society of Japan, Vol.55, No.2, pp.107-118, 2002.

[8] ITU-R, *Recommendations Radio wave propagation*, vol. P Series - Part 1, P.372-6, 1998.

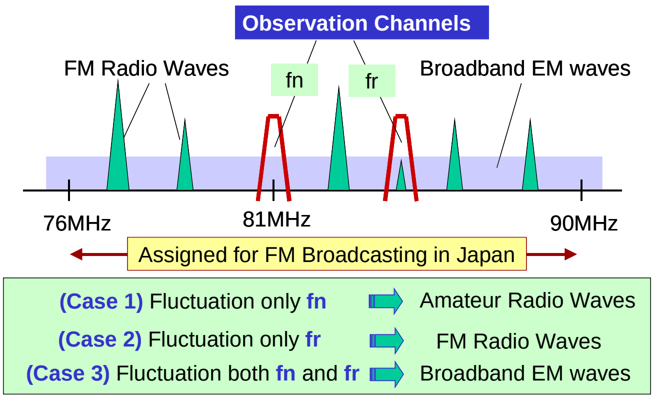

Fig. 1. Dual frequency method in VHF band

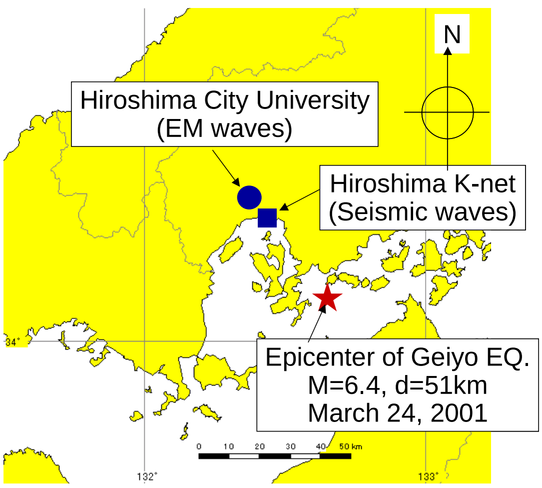

Fig. 2. Epicenter and observatories at Geiyo EQ.

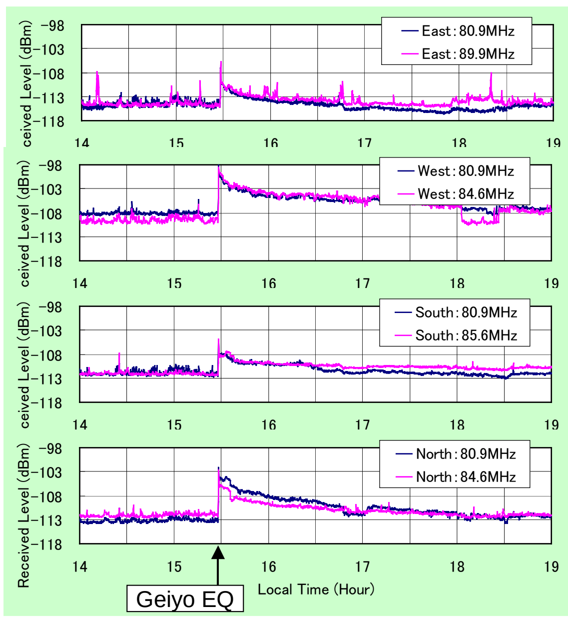

Fig. 3. Detected EM waves in VHF band at Hiroshima City Univ. on March 24, 2001, at Geiyo EQ.

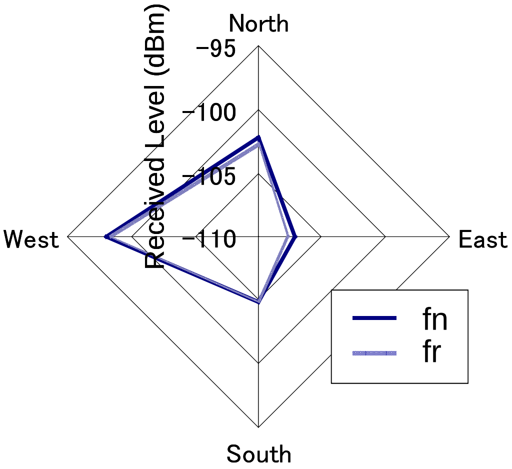

Fig. 4. Peak Levels of co-seismic EM waves detected at Hiroshima City Univ. at Geiyo EQ.

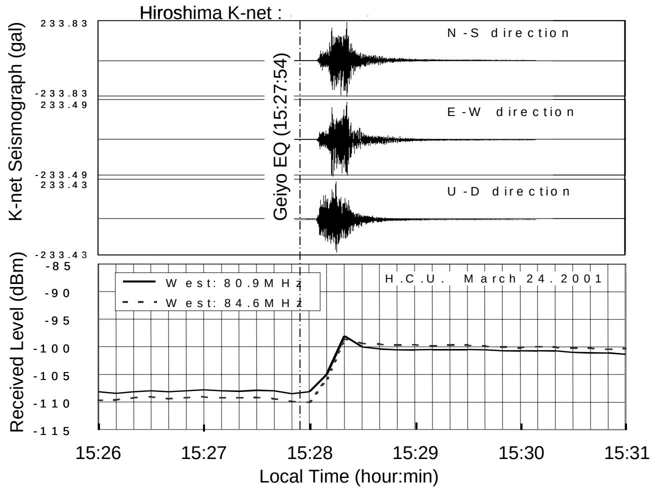

Fig. 5. Time variations of seismic waves detected at Hiroshima K-Net and EM waves detected at Hiroshima City Univ. at Geiyo EQ.

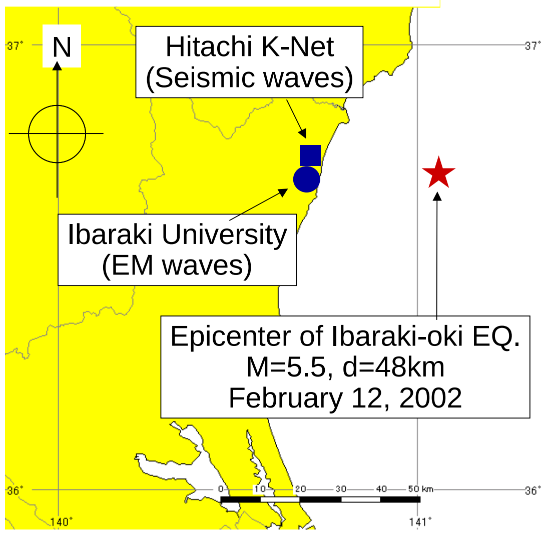

Fig. 6. Epicenter and observatories at Ibaraki-ken-oki EQ.

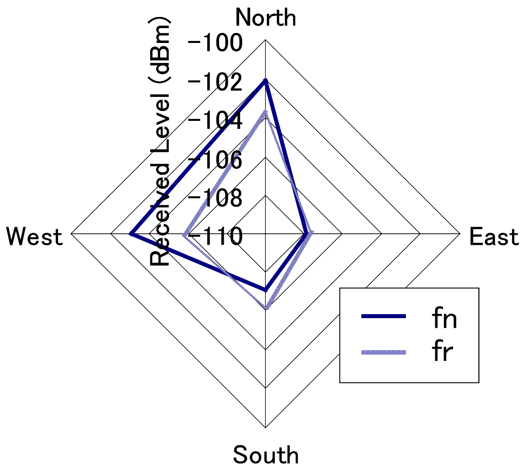

Fig. 7. Peak Levels of co-seismic EM waves detected at Ibaraki Univ. at Ibaraki-ken-oki EQ.

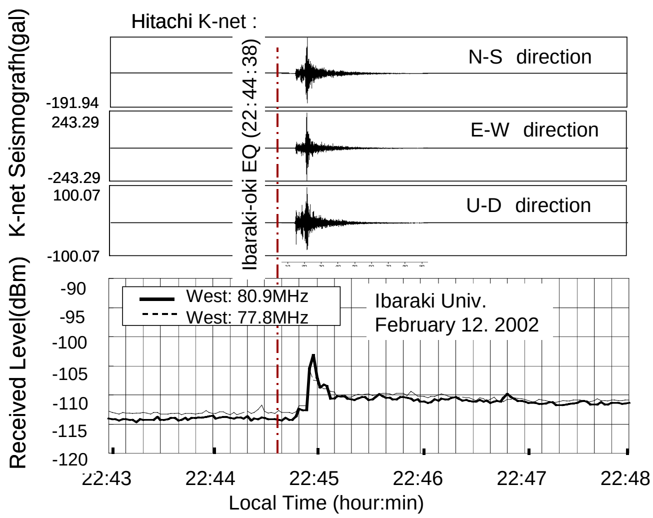

Fig. 8. Time variations of seismic waves detected at Hitachi K-Net and EM waves detected at Ibaraki Univ. at Ibaraki-ken-oki EQ.