EARTH-ORIGIN EM PULSES AS A PRECURSOR OF EARTHQUAKES

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Abstract

We detected an intense earth-origin electromagnetic (EM) pulse when an earthquake occurred. From the detail analysis of the detected pulse, we could identify that the source location of the EM pulse was on the earthquake epicenter. Then we examined EM pulses before and after the earthquake. Furthermore, we detected less EM pulses before another weak earthquake. From comparison of these two earthquakes, we found that the detection frequency of EM pulses would depend on the magnitude of earthquake. From this trend, it is expected that the earth-origin EM pulses could be a precursor of earthquake.

1. INTRODUCTION

We have been measuring extremely low frequency (ELF) noises in the earth since 1999. Fig. 1 shows the observation system for detecting electromagnetic (EM) noises in the earth, which was constructed in the campus of Kyoto Sangyo University, Kyoto, Japan. An EM sensor system was inserted into the bore-hole of 10 cm in diameter and 100 m in depth which was made of non-electrically conductive materials in order not to shield the EM sensors from weak EM fields in the earth. Another sensor was installed above the ground. Noises detected in the earth were almost power line harmonics and natural EM impulses. From July to September in 2000, many electric pulse noises were detected, and in October, an earthquake occurred at about 200 km west of our observation site. One year later, Geographical Survey Institute of Japan reported that the Eurasia plate of the western Japan had been moving to east about 1 cm from July to September 2000, which was unusually large movement during such the short period of a few month in 2000, that is the same period when the pulse swarms had been detected in Kyoto Sangyo University. Outstanding features of the detected EM pulses were that their spectral forms have shown a clear lower-frequency cut-off at around few hundred Hz, and their intensities in the earth were stronger than those above the ground. Therefore, we had a speculation that the EM pulses detected during the period in 2000 were generated in the deep earth and some of their energy had been leaking out of the ground surface during their propagations in a kind of waveguide formed by electrically conductive layer in the deep earth and the ground surface [1]. For further investigation of properties of the earth-origin EM pulses, we have developed a system for obtaining arrival directions of EM pulses "unpublished"[2]. We applied the EM system to find arrival directions of earth-origin EM pulses. Through continues observation by the system, we found

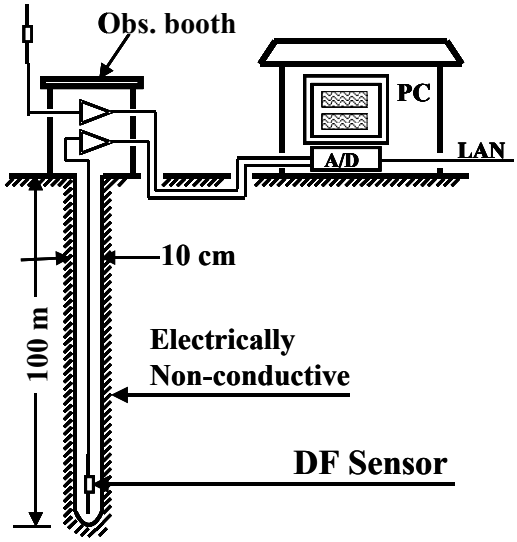

Fig. 1. System for detecting earth-origin EM pulses. DF (direction finding) sensor is inserted into the bore-hole [1]

interesting features of EM pulse detections. We here introduce some of events of EM pulses which would be one of precursors of earthquakes.

2. MEASUREMENT SYSTEM AND DATA ANALYSIS

We have already submitted a paper on the technical method for finding arrival directions of EM pulses "unpublished" [2]. The sensor system consists of a vertical dipole antenna of 10 m tip-to-tip for detecting vertical electric field E_v, and horizontally- and orthogonally arranged two search coils (10,000 turn coils of 8 cm in length) for detecting horizontal component of wave magnetic field H_h. Since the duration of waveforms of earth-origin EM pulses is extremely short less than a few milliseconds, and the timing of their detections is unpredictable, the system is set to capture the waveforms and to acquire them into a personal computer automatically when the sensors detected peek values of the pulse exceeding a preset threshold level by means of the pre-triggering function of AD converter connected to a personal computer. In the same paper, we also reported a method of data processing for deriving frequency dispersion characteristic (f - t) curves from short impulsive waveforms. From the derived dispersion characteristics, we could obtain amplitudes and phases of E_v and H_h in each frequency. Then we could determine arrival directions in each frequency from pointing vectors $E_v \times H_h$ taking into account of a phase relation between them. From obtained arrival directions of many frequency components containing in the EM pulse, we could obtain frequency-dependent arrival directions of the EM pulse. An exact direction which was pointing toward the EM pulse source was determined.

2. AN EM PULSE DIRECTLY EXCITED BY AN EARTHQUAKE

Through continuous observation of EM pulses, we detected an earthquake related EM pulse. We also submitted another paper on the analysis of the detected EM pulse, which can provide a clear frequency dispersion characteristic curve (f – t curve) "unpublished" [3]. The frequency dispersion curve of the detected EM pulses was similar to that of tweek atmospherics which are usually generated by lightning and are propagating in a kind of waveguide formed between the electrically conductive ionosphere and the ground surface [4, 5]. The theoretical dispersion formula for the tweek atmospherics have been already discussed by Yano et al. [6]. As described in the previou section, since we could obtain frequency-dependent arrival directions of EM pulses, we could find the direction toward the source location. On the other hand, we compared the derived dispersion (f- t) form to several theoretical dispersion curves for different propagation distances as a parameter in the formula. Then we could pick up a theoretical dispersion curve which well matched with the measured one, and we could find the propagation distance of the EM pulse by its parameter. Finally, we found that the EM source location was just on the earthquake epicenter. Fig. 2 show the relation between the source location of the EM pulse and the earthquake epicenter "unpublished"[3].

From the fact that the duration of EM pulses was less than a few millisecond, their generation mechanism would be regarded as the piezo-electric effect. Therefore, detections of EM pulses and identifications of their source locations are very useful for pointing plausible places where dynamical impacts have been imposed to the earth crust. Therefore, we can regard that earth-origin EM pulses would be one of precursors of earthquakes.

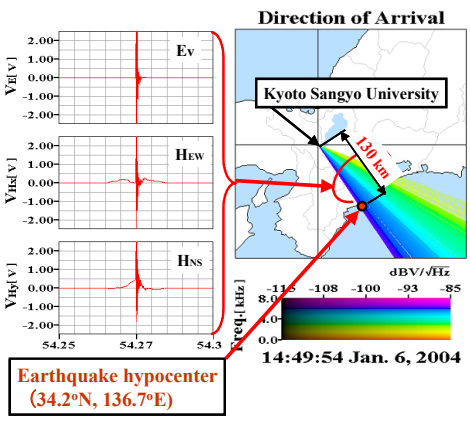

Fig. 2 Coincidence between the source location of EM pulse and earthquake epicenter "unpublished" [3].

3. TIME VARIATIONS OF ARRIVAL DIRECTIONS OF EARTH-ORIGIN EM PULSES BEFORE AND AFTER EARTHQUAKES

As we found that the earth-origin EM pulses were good indicator of dynamical impacts to the earth crust, we examined a trend of detection frequency of EM pulses and their directions before and after the earthquake. Fig. 3 shows plots of arrival directions of EM pulses detected before and after the earthquake (M 5.5) occurred on January 6, 2004. In the figure, the vertical axis indicates arrival directions in which the north direction is at the top and other directions are shown to the bottom. The horizontal axis indicates the time for about 6 days. The occurrence time of the earthquake (14:50 JST of January 6, 2004) is indicated by the vertical solid line. In the figure, EM pulses began to appear about two days prior to the earthquake. The time series of plots had been concentrating to a direction toward the earthquake epicenter just before the earthquake, which suggests that dynamical impacts to the earth crusts had been increasing with time. Just after the earthquake, no EM pulse had been detected for a while . However, many pulses have begun to appear again after the brief cease. These phenomena might be caused due to some reactions to rather strong movement of the earthquake (M 5.5) . Since many EM pulses were detected during the period of few days before and after the earthquake, the present earthquake could be classified into a criterion of rather strong event. Similar trend of EM detections was observed when another larger earthquake (M 6.8) occurred on September 5, 2004, in which more EM pulses than in Fig. 3 were detected even two days before the earthquake, and their source locations have been moving.

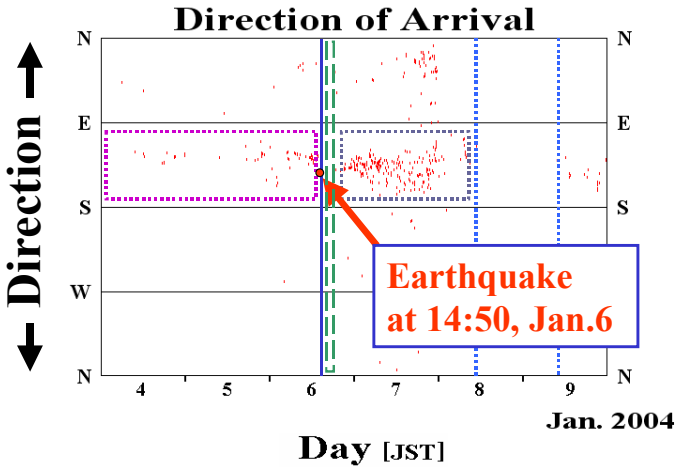

Fig. 3. Plots of arrival directions of EM pulses detected before and after the earthquake (M 5.5) occurred on January 6, 2004.

On the other hand, we had another event in which we have few detections of EM pulses before earthquakes. Fig. 4 shows detection times of EM pulses during six days, in which detection times are indicated by arrows. During these six days, we detected only eleven EM pulses as shown by arrows. In the figure, we show only three frequency-dependent arrival directions of EM pulses as examples, which shows that all arrival directions of EM pulses had pointed toward the same directions as those in the exemplified maps. We had checked the data during the period of two weeks including these six days, and we found that it had been extremely quiet in EM noise condition during the period. However, the first EM pulse appeared on October 22, that is about 5.5 days before an earthquake (M4.5) occurred at 21:27 JST on October 27 which is shown by the red arrow in the figure. Eight EM pulses among eleven were detected on October 26, that is one day before the earthquake. The concentrating trend of their detection is the similar to those shown in Fig. 3. However, this event could be classified into another criterion of weak events.

From these three cases, we found that the earthquakes with large magnitude excited many earth-origin EM pulses, and those with small magnitude provided less excitations of EM pulses. Thus we call it M-dependence of EM pulse detections. From the M-dependence and the trend of the concentrated series of plots leading to the earthquake, the earth-origin EM pulses would become important precursor of earthquakes. A statistical study on a relation between the detection density of the EM pulses and the earthquake magnitude would be a good indications for earthquakes.

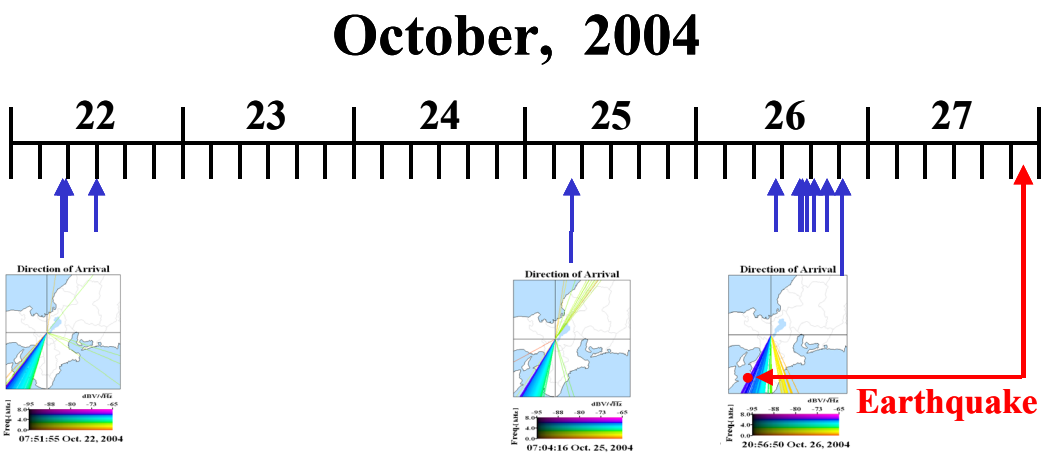

Fig. 4 Detection times of earth-origin EM pulses in the criterion of rare excitation. During six days, only eleven pulses were detected. Most of them were pointing to same directions (at the blue edge of the sector shape) as shown in the maps. An earthquake of M4.5 occurred at 21:27 JST on October 27 as shown by a red arrow. The earthquake epicenter is indicated by a red dot on the map.

References

[1] M. Tsutsui, (2002), Detection of earth-origin electric pulses, *Geophys. Res. Lett.,* 29(8), doi: 10.1029/2002GL013713.

[2] Minoru Tsutsui, Sigeo Konagaya and Tadayoshi Kagawa (2005), A Method of Direction Finding for Dispersive Electromagnetic Pulses, submitted to *IEICE*.

[3] Minoru Tsutsui (2005), Identification of Earthquake Epicenter from Measurements of Electromagnetic Pulses in the Earth, submitted to *Geophys. Res. Lett.*

[4] R. Barr (1974), Multimode propagation in the earth-ionosphere waveguide, Holtet, J. A. (Eds.), *ELF-VLF Radio Wave propagation*, 225-231, D. Reidel.

[5] M. Yamashita (1978), Propagation of tweek atmospherics, *J. Atmos. Terr. Phys.*, 40, 151-156.

[6] S. Yano, T. Ogawa and H. Hagino, (1991), Dispersion Characteristics and Waveform Analysis of Tweek Atmospherics, *Environmental and Space Electromagnetics,* (Ed) H. Kikuchi, 227-236, Springer Verlag, Tokyo.