DETECTION AND RADIATION AREA ESTIMATION OF ANOMALOUS ENVIRONMENTAL ELECTROMAGNETIC WAVE RELATED TO EARTHQUAKE PRECURSOR

Tokiyasu Sato[1], *Ichi Takumi*[1], *Masayasu Hata*[2], *and Hiroshi Yasukawa*[3]

[1]Nagoya Institute of Technology, Gokiso-cho, Showa-ku, Nagoya 466-8555, Japan
tkys@ics.nitech.ac.jp
[2]Chubu University, Matsumoto-cho, Kasugai-city, Aichi 487-8501, Japan
[3]Aichi Prefectural University, Nagakute-cho, Aichi-gun, Aichi 480-1198, Japan

1. INTRODUCTION

Japan is one of the countries where a lot of earthquakes occur. The occurrence of the large earthquake will be feared in the near future. It is necessary to predict the earthquake to minimize the damages due to the earthquake.

Anomalous radiation of environmental electromagnetic (EM) wave is reported as a portent of earthquakes. Then, we have been observing EM radiation in the ELF band at about 40 sites in Japan. Each observation site has three loop coil antennas with east-west, north-south, and vertical directivity. The three antennas observe the variation in magnetic flux densities. Observation system samples EM level and recorded the absolute average for 6 seconds.

Our goal is to predict earthquakes by detecting anomalous EM radiation. Then, we proposed the detecting method of anomalous EM radiation by using the magnetic field azimuth calculated from the observed signals [1]. However, the earthquake prediction requires not only detection of anomalous EM radiation but also estimate of EM radiation area. If the EM radiation area can be estimated, the estimation of the epicenter is also possible.

In this paper, we propose the method of area estimation in the anomalous EM radiation. We applied the proposed method on the day when an anomalous radiation is detected. And we show the estimation result of the EM radiation area.

2. DETECTION OF ANOMALOUS RADIATION

Detection of anomalous radiation uses magnetic field azimuth. A magnetic field azimuth θ is calculated by equation (1) using east-west signal A_{E-W} and north-south signal A_{N-S}:

$$\theta = \arctan \frac{A_{N-S}}{A_{E-W}}, \quad 0^\circ \le \theta \le 90^\circ. \tag{1}$$

Observed signals are a nonnegative value, thus the magnetic field azimuth has two values θ and $-\theta$. This paper adopts only θ.

We consider observed signal which contains the anomalous EM radiation caused by the crustal activity has notable fluctuation in magnetic field azimuth. To detect this fluctuation, we calculated the cross-correlation in magnetic field azimuth (call as azimuthal cross-correlation hear in after).

One of the large earthquakes occurred in the near past is 2005 West Off Fukuoka Prefecture Earthquake (M7.0) on March 20, 2005, 10:53 (JST). We calculate the azimuthal cross-correlation every day by using observed signals before this earthquake, and show the example of detecting the earthquake precursors. The location of epicenter and observation sites is shown in Fig.1.

Fig.2 shows the transition of the azimuthal cross-correlations between Unzen, Nagasaki and other 5 observation sites all over Japan (see in Fig.1) during 48 days before the earthquake. The azimuthal cross-correlation has notable fluctuation twice at A and B. This result indicates the occurrence of the anomalous EM radiation in A and B.

3. ESTIMATION OF ANOMALOUS RADIATION AREA

It is necessary to clarify that detected anomalies are an earthquake precursor. Then, we estimate the anomalous EM radiation area. If the epicenter is included in its area, we assume that detected anomalies are an earthquake precursor.

The estimation of anomalous EM radiation area uses the azimuthal cross-correlation. To evaluate an azimuthal cross-correlation, we made the EM radiation model shown in Fig.3(a). Calculate the azimuthal cross-correlation between the reference

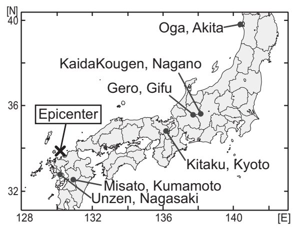


Fig. 1. Location of epicenter and observation sites.

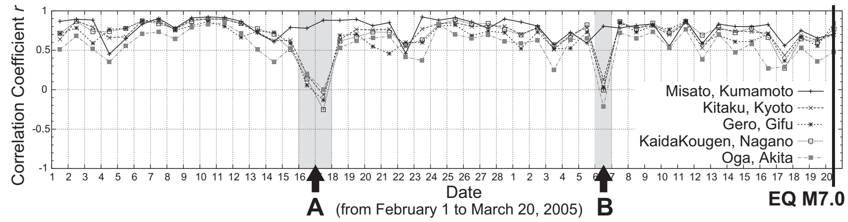
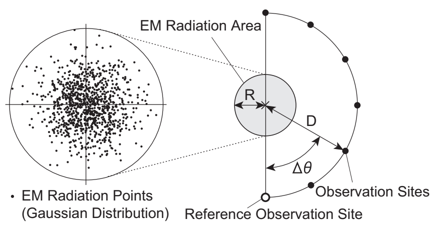
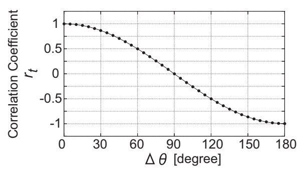


Fig. 2. Transition of azimuthal cross-correlations between Unzen and other 5 observation sites during 48 days before the earthquake.

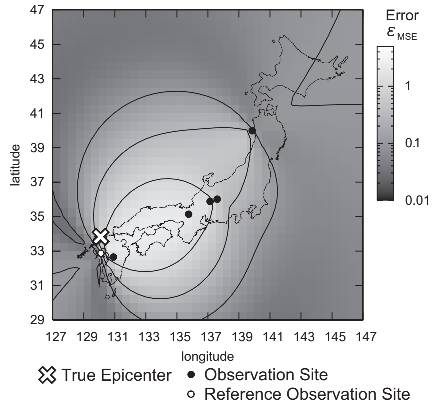


(a) Model

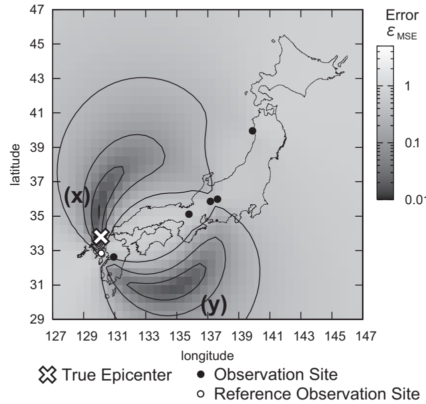


(b) Result ($D/R = 10$)

Fig. 3. EM radiation model and simulation result of azimuthal cross-correlation.



(a) Usually (Feb. 5, 2005).



(b) Anomaly (Mar. 6, 2005 (Fig.2 B)).

Fig. 4. Error distribution in azimuthal cross-correlation.

observation site and the other observation site, the result is shown in Fig.3(b). $\Delta\theta$ is an angle between the observation sites when the origin is the center of EM radiation area. The cross-correlation r_t has changes from the positive correlation to the inverse correlation as $\Delta\theta$ increases. This relation can be approximated by cosine function as shown in the following:

$$r_t = \cos\Delta\theta. \tag{2}$$

When the center of EM radiation area is defined as the epicenter, $\Delta\theta$ can be calculated. The azimuthal cross-correlation calculated from the observed signals is assumed to be r and we calculated the error ε_{MSE} between r_t and r:

$$\varepsilon_{MSE} = \frac{1}{N-1}\sum_{i=1}^{N-1}(r_{ti} - r_i)^2. \tag{3}$$

i is an index of observation site, and N is a number of observation sites. If ε_{MSE} decreases when an anomalous EM radiation occurred, it is highly possible that the defined epicenter is included in the anomalous EM radiation area.

Fig.4 shows the distribution of the error in usual day and anomaly day when a virtual epicenter is arranged at equal distances. Usually, it has the error distribution like Fig.4(a). On the other hand, it has the error distribution like Fig.4(b) on an anomaly day. Fig.4(b) has two areas (x), (y) where the error is locally minimum. There is a possibility that these areas are an anomalous EM radiation area. Especially, (x) includes a true epicenter, it can be said that (x) is the EM radiation area related to the earthquake.

4. CONCLUSIONS

We proposed the detection method of anomalous EM radiation and the estimation method of EM radiation area by using azimuthal cross-correlation. The proposed method showed the possibility that the anomalous EM radiation was caused around the epicenter before the earthquake.

5. REFERENCES

[1] T. Sato et al., "Anomaly Detection of Environmental Electromagnetic Wave based on Time Fluctuation and Cross-Correlation in Magnetic Field Azimuth," *Proc. of ISITA2008*, pp.1134-1139, 2008.