THREE-AXIAL OBSERVATION OF ELF EMISSIONS AND EM PRECURSOR OF LARGE-SCALE EARTHQUAKES IN JAPAN

Masayasu Hata
Faculty of Engineering, Chubu University
E-mail: hata@cs.chubu.ac.jp

Abstract: We present an observation equipment at Extremely Low Frequency (ELF) band for electromagnetic (EM) precursors of earthquakes and volcanic eruption. By making use of the highly sensitive equipment of the order of sub-pico Tesla per root Hertz, we have detected many precursors of earthquakes and volcanic eruptions for these ten years. In this paper, we discuss EM precursors of large-scale earthquakes.

Key words: ELF, precursor, large-scale earthquake, three-axial observation

1. Introduction

Earthquakes and volcanic eruption are huge menaces to the mankind, but they are just local events as compared with the solar-terrestrial phenomena around the earth. Therefore, in order to detect an EM precursor of crust anomaly, the solar-terrestrial EM radiation must be removed. A highly sensitive observation equipment was developed with a window observation frequency in the ELF band by rejecting the solar-terrestrial radiation in the ULF band.

We have been detecting many precursors of moderate and large earthquakes and also volcanic eruptions. In this paper, we discuss the precursors of large earthquakes including the recent M7.0 Offshore-Miyagi earthquake on May 26, 2003. We could find that large earthquakes with magnitude exceeding 7.0 take a tortuous course for a long period of one year, which makes the prediction of a large earthquake still a difficult problem.

2. Observation Equipment

In order to detect the tectonic anomaly through weak EM radiation as a precursor, it is a vital necessity to consider the precursor's spectrum and immunity from the earth environmental EM noises generally in the ULF band. One of the important factors for the design of an equipment was the selection of observation frequency. A matter with size s radiates EM spectrum around at the resonant fundamental frequency of 2s/v, where v is light velocity of the matter. Therefore, the precursor abounds with a higher frequency spectrum than that of the solar-terrestrial phenomena.

Observation in the ELF band ranging from 10-300Hz was effective to remove the interferences from the magnetosphere and ionosphere and further sensor's moving noise, that are prominent in the low frequency band of ULF.

The equipment in the ELF band has further a potential to get rid of lightning noise of the front, prominent in the VLF and HF bands. Additionally, the manmade noise of power line sources at 50 and 60 Hz, was reduced by applying the prime number observation frequency, such as 223 and 17 Hz. We also utilized the tuned sensor and narrow

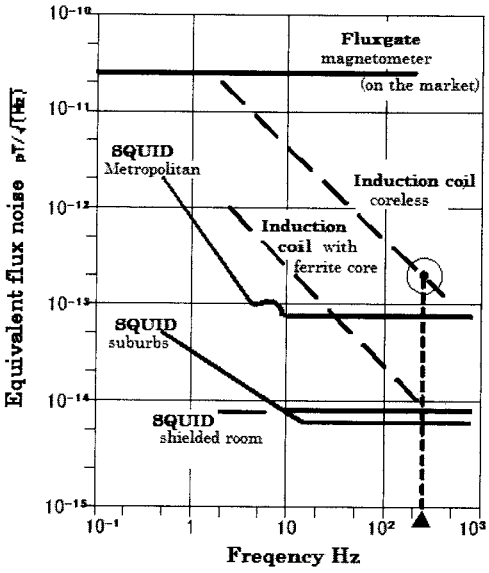

Fig.1 Sensitivity comparison of several magnetometers

bandwidth amplifier and data processing unit with integration time of 6 and/or 150 seconds. We utilized induction coreless coil sensors

with diameter of about 50cm at 223Hz and super-permalloy iron core sensors of 70cm in length at 17Hz. A high sensitivity of the order of sub-pico Tesla per root Hertz was attained in the ELF band.

The three-axial sensing of the EM precursor gives rise to discrimination of the source areas. The incident angle is determined from the ratio of two horizontal amplitudes, and the vertical component suggests the source being close to the site within about 10-20km, because the vertical components are absorbed by the lossy crust.

The observation sites of about forty have been located from Hokkaido to Kyushu, with more than half being in the Central Japan. The sites have been connected to our processing center by public telephone lines once a day to exchange data and control command.

3. EM Precursor of Large-scale Earthquakes

Figure 2 shows the N-S magnetic flux amplitude detected at Usami, Itoh-city, Central Japan for two weeks preceeding the disastrous earthquake (M7.8, depth of 34km) of Offshore Okujiri Islands, South-West Hokkaido, occurred on July 22, 1993.

The EM precursor propagated over about 800km from the South–West Hokkaido was superposed on the background noise and detected with an irregular daily change as in Figure 2. We can also notice the rise-up of baseline just before the earthquake, which means the additional radiation signal increased. The precursor signal was small as the background signal level.

The horizontal flux amplitude is due to lightning noise of tropical areas and it normally shows a smooth daily day-night change. The propagation is taken place in the Earth-ionosphere waveguide, whose height and density are daily changed due to the solar radiation. The signal becomes the background noise for the observation. For the case of weak precursor, the daily change is irregularly modified.

Figure 3 shows another example of precursor as a deviation from the daily change at the two sites of Omaezaki, Shizuoka and Usami, Itoh-city, Central Japan, for a week prior to the Far-offshore Sanriku earthquake (M7.5) of the type of sea trench occurred on December 28, 1994.

The distance between two sites is about 100km, and to the epicenter is about 700km. The two observation sites detected almost the same radiation. It means that we detect the same signal at the two sites and not of the manmade, since the source cannot be present in the center area of the two sites and cannot give such a radiation level in the ELF band.

The radiation was stronger and more irregular than the case of Okujiri Islands. It may be either due to the crust structure underground or the propagation path of sea surface in the place of mountains.

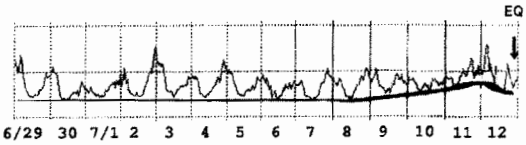

Fig.2 EM precursor for two weeks of Southwest Hokkaido M7.8 earthquake on July 12, 1993 observed at Usami, Itoh, Central Japan with distance of about 800km.

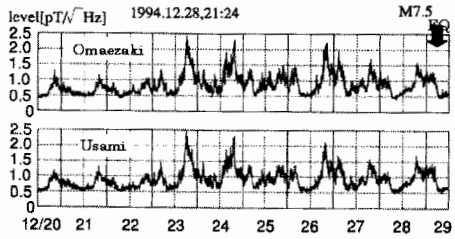

Fig.3 EM precursors of Far–offshore Sanriku M7.5 earthquake on Dec.28, 1994, at Omaezaki and Usami spots for ten days of Dec.20-29, 1994.

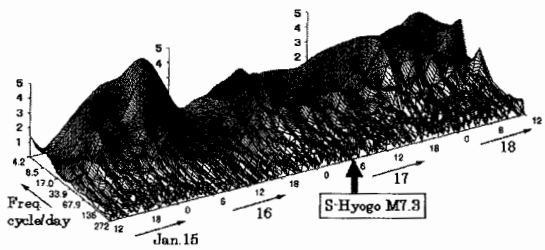

Fig.4 South-Hyogo M7.3 earthquake on Jan. 17, 1995. Wavelet supectrum of precursor taken at Usami, Itoh.

Figure 4 shows the wavelet spectrum of the anomalous radiation observed at Usami, Itoh-city for the South-Hyogo M7.3 earthquake of the type of inland on January 17, 1995. The observation distance was about 400km. We can see a calm period of the spectrum one day before the quake and severe radiation at the higher frequency just before and after the shock. The radiation strength at Usami was not so strong with only several times of the background variation, and the maximum radiation of about six times occurred one week before.
We could observe the same event at the Unzen volcano, Kyushu Southwest Japan. The distance was about 500km. Figure 5 shows the record on the shock day of the seismometer (upper two traces) and the three-axial flux records (bottom three flux records) of the quake. The flux decreased abruptly three hours before the quake and then started a vibrating radiation half an hour before the quake (Fig.6). The radiation was rather strong at the Unzen volcano. This fact may be explained in terms of the reality that the focus and the volcano are related through the long trench named the Median tectonic line.

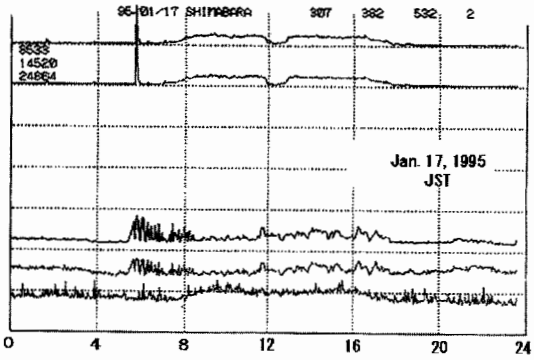

Fig.5 South-Hyogo M7.3 eartquake on Jan.17, 1995. Main shock on the seismometer (upper) and three-axial EM precursor (lower EW,NS and V) taken at the Unzen volcano on the day of quake.

Figure 7 shows anomalous radiation of the offshore Miyagi quake (M7.0, depth of 71km, Northeast Japan) on May 26, 2003. The radiation anomaly was observed for about half a month, ten days before and one week later the shock. The observation site was Wakayanagi, Miyagi Japan, and the epicenter distance was East 60km. The observation distance was short, but the focus was deep in the sea. Therefore, the radiation level was thought not so bigger. Two months later the shock, Northern Miyagi quake of M6.2 occurred in the depth of 12 km, of the type of inland.

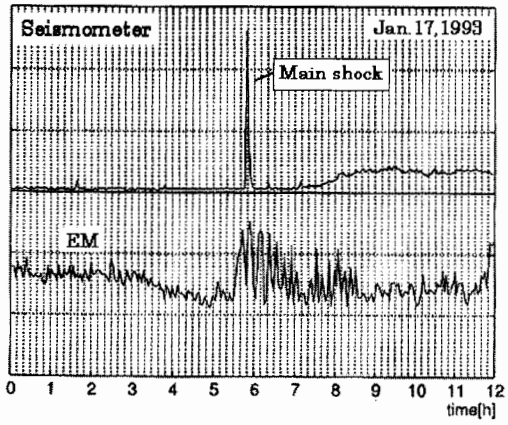

Fig.6 Enlarged record (EW) of half a day of Fig.5.

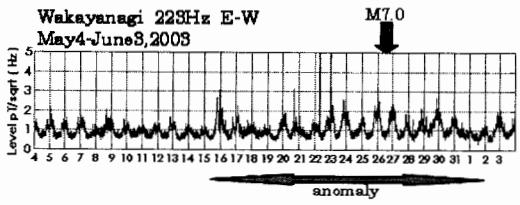

Fig.7 Offshore-Miyagi M7.0 earthquake (depth of 71km) on May 26, 2003. EM (E-W) precursor taken at Wakayanagi, Miyagi, west of about 60km of epicenter, May 4-Jun 3, 2003.

Figure 8 shows the anomalous radiation observed at the Wakayanagi site, with the distance of 30km. In this case, we could detect much more clear anomalous radiations for one more month than that of the offshore Miyagi M7.0. Further, the anomalous radiation was detected at the Oga-city site, Akita Japan, about 200km apart. Some geologists say that a tectonic line is possibly presented between the two peninsulas of Oga to Ojika, Miyagi.

One more important thing for these Miyagi shakes was that an early anomaly radiation was detected for about one and a quarter year preceding the offshore Miyagi quake. Figure 9 shows the anomalous radiation obtained at the Wakayanagi site. The

radiation suddenly started about eight hours preceding the Northern Miyagi quake (M4.3,) on February 13, 2002, which was within 10km from the observation site. The radiation constantly continued up to the Offshore-Miyagi two quakes of M4.0 ,M4.6, on January 27, 2003. The quake activities tended to move to the offshore area at this moment and the radiation was weakened up to the main shock.

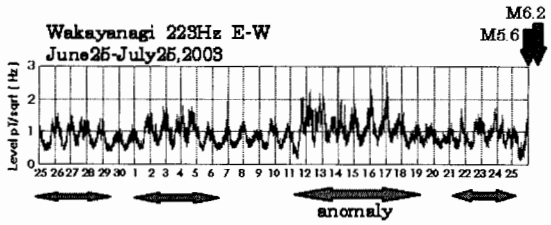

Fig.8 North-Miyagi earthquake (M6.2, depth of 12km) on July 26, 2003. EM (E-W) precursor taken at Wakayanagi, Miyagi during June 25 to July 25, 2003.

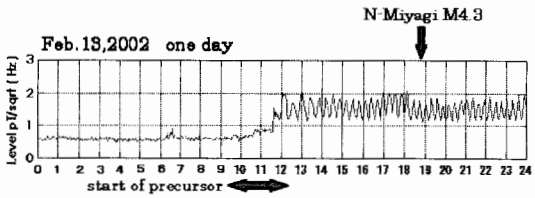

Fig.9 EM anomaly started on Feb.13, 2002, 8 hours preceding to the Morth-Miyagi M4.3 earthquake. Taken at Wakayanagi, Miyagi on the day of quake.

4. Conclusion

Our ELF band highly sensitive receiver is found to be of sufficient ability to selectively detect EM precursors. In this paper, the precursor for large-scale earthquakes with magnitude exceeding 7 was discussed, and we could extract correspondences of the precursor with the earthquakes. The detection ability of the precursor was shown to be greatly dependent on the epicenter distance, depth and on the state of crust or tectonic line of the preparing area. If we could build up a more dense observation network taking into account those conditions, we could get more knowledge on the earthquakes and the model of prediction.

References

[1]S. Niwa, H.Yasukawa, I. Takumi and M. Hata, "A Study on Precursor Signal Extraction with PCA for Predicting Significant Earthquakes", IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences, Vol.E86-A, No.8,2003.

[2] H.Yasukawa, S.Niwa, M.Hata and I.Takumi, "On Signal Processing for Seismic Electromagnetic Wave Radiation Application to Great Earthquake Prediction", Proc. of The IEICE International Conference on Fundamentals of Electronics, Communications and Computer Sciences, pp.12-15-12-18, 2002.

[3] M. Hata, "Electromagnetic-Wave Radiation in Central Shizuoka in 2001 and Its Slip Model", Proc. of the International Symposium on Slip and Flow Processes in and below the Seismogenic Region, pp.80-1- 80-8, 2001.

[4]S.Adachi, H.Yasukawa, I.Takumi and M.Hata,"Signal Processing and Sonification of Seismic Electromagnetic Radiation in the ELF Band", IEICE Transactions on Fundamentals of Electronics, Communications and Computer Sciences, Vol.E84-A, No.4, pp.1011-1016,2001.

[5] M. Hata, I. Takumi and H. Yasukawa, "Electromagnetic-wave radiation due to diastrophism of magma dikegrowth in Izu-Miyake volcanic eruptions in Japan in 2000", Natural Hazards and Earth System Sciences (EGS), Vol.1, No.1, pp.43-51,2001.

[6] M.Hata, I.Takumi, S.Yabashi, X.Tian, "An anomaly of ELF band vertical flux as a precursor of dome formation at Unzen volcano and its model Analysis", The Special Issue of Phys. Earth Planet. Int.(PEPI) on Electromagnetic Effect of Earthquakes and Volcanoes, Vol. 105, pp. 271-277,1998.

[7] M.Hata, I.Takumi, S.Yabashi, A.Imaizumi, "ELF horizontal magnetic flux precursor of the moderate M5.8 Yamanashi'96 inland earthquake", J. Atmospheric Electricity, Vol.16, No.3, pp.199-220, 1996.

[8] X.Tian and M.Hata, "Analysis of Seismogenic Radiation and Transmission Mechanisms", J. Atmospheric Electricity, Vol.16, No.3, pp.227-235, 1996.

[9] M.Hata, and S.Yabashi, "Observation of ELF radiation related to volcanic and earthquake activities", In:M.Hayakawa, Y. Fujinawa(Eds.), "Electromagnetic phenomena related to earthquake prediction", Terra Scientific Publishing Comp. (TERRAPUB),Tokyo,pp.159-174, 1994.