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Signal Processing Scheme For Earthquake Prediction Analysis In Seismic Electromagnetic Radiation

Hiroshi YASUKAWA, Seiji ADACHI, Ichi TAKUMI* and Masayasu HATA

Faculty of Information Science and Technology, Aichi Prefectural University

* Faculty of Engineering, Nagoya Institute of Technology

1. INTRODUCTION

According to a theoretical estimation [1], electromagnetic wave due to seismic activities can be radiated as an indication of an earthquake. The radiation is considered to originate in electromechanical process associated with the tectonic movements, and in electrochemical reactions such as the oxidization of reactive materials in the earth crust, which are ascending from deep under the ground with the magma, although the detail of the mechanism has not been understood.

By detecting the radiation, there is a possibility to predict an occurrence of an earthquake and to avoid the disastrous situation. We have already developed over forty observation stations measuring the atmospheric electromagnetic radiation of 233 Hz frequently in extremely low frequently (ELF) band [2] [3]. In the frequently region lower than several tens Hz, radiation due to a larger scale movement of the magnetosphere surrounding the earth perturbed by the solar wind dominate. In the region higher than about a thousand Hz, a background noise caused by atmospheric discharges in the tropical regions is increased. The 223 Hz is also chosen not to be a multiple of the frequency of the power supply, that is 50 or 60 Hz.

In spite of the deliberate selection of the observed frequency, the seismic radiation is still accompanied by a background noise caused by atmospheric discharges in the tropical regions. The magnitude of the noise varies daily, with the period of twenty-four hours. This is because the altitude of the ionosphere is raised in the night, and descends during the daytime. The larger the distance between the ionosphere and the surface of the earth, the smaller the attenuation of the noise propagating through them.

The magnitude of the seismic radiation oscillates much faster than the daily change of the background noise. In this paper we develops a signal processing method that is able to discriminate the seismic radiation from the background noise. It also presents a method to transform the processed signal of the radiation to sound via the sonification [4], which is now often applied for the clinical signal processing [5]. The auditory display facilitates searching anomalous seismic radiation immediately, which leads us to predict an occurrence of an earthquake.

2. SIGNAL PROCESSING SCHEME

A signal detected by an observation station in Ibaraki Osaka in August '99 is shown in Fig. 1(. At 5:33am of August 21st, an earthquake of magnitude 5.5 was happened in northern part of Wakayama Prefecture Japan. The observation station is about a hundred-kilometer away.

To extract the seismic radiation, the low frequency (LF) component less than 8cycle/day is filtered out from the signal. The LF component is mainly composed by the noise slowly varying (with frequency larger than 1 cycle/day). The amplitude of the residual fast oscillating component is then calculated. The long-term change of the seismic activity can be regarded as the LF component of the amplitude. The cutoff frequency for the low-pass filtering is set to 0.5 cycle/day.

Thick lines in Fig.1 represent the long-term change of the seismic activity. For comparison, the LF components (with frequency smaller than 0.25 cycle/day) of the original signals are also shown by the thick dashed lines.

The largest amplitude of the seismic activity is observed in August 20, that is one day before the earthquake occurs. The peak is outstanding as compared with other local maxima observed in these months. The LF component of the original signal also has a peak in August 20. The seismic activity extracted through the above process is more promising for the earthquake prediction than the LF component of the original signal.

3. DATA MINING AND SONIFICATION

We have attempted to generate sounds modulated by the long-term change of the seismic activity. Both of the amplitude and the frequency of a steady sound with a sawtooth wave were modulated. A sound of n sounds is generated for the observed data of n days.

The amplitude and the spectrogram of the sounds for the data shown in Fig. 1 are depicted in Fig. 2 Note that just before the earthquake occurs at 21st of August, both of the amplitude and frequency of the sound are suddenly raised. This change sounds as if it alarms against the earthquake that occurs shortly after.

We applied the proposed method for not only data above mentioned but also another observed data. We obtained valuable results for other data. Thus the proposed signal processing approach has a great possibility for the earthquake prediction.

Applying the auditory display presented here to all the radiation data collected by ourselves, we are now discussing the relation between anomalous radiation and earthquakes ever happened.

4. CONCLUSIONS

The signal processing method to discriminate the earthquake activity from the background noise in the observed electromagnetic wave in the ELF band was investigated. The actual example of the analysis shows that the method has a great possibility for the earthquake prediction. The auditory display is also shown to be useful to find anomalous radiation among the massive data collected from the observation stations.

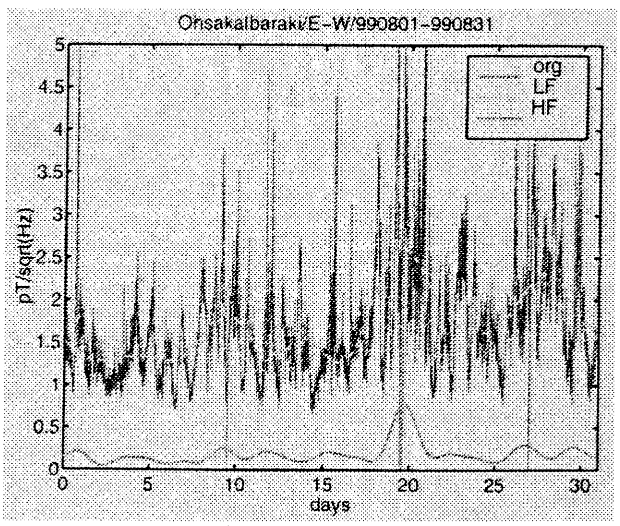

Fig. 1. A signal detected at an observation station

In order to implement a practical system, it is important to accumulate examples indicating good correspondence between the earthquake activity extracted by the signal processing and the actual earthquakes. We are now testing the method by applying it to all the observed radiation data collected by ourselves. We also investigate to implement a system for earthquake prediction.

REFERENCES

[1] X. Tian and M. Hata, "Analysis of seismogenic radiation and transmission mechanisms", J. Atmosphere Electricity 16(3) pp.227-235 (1996).

[2] M. Hata, I. Takumi, S. Adachi and H. Yasukawa, "An analytical method to extract precursor from noisy atmospherics", Proc. of European Geophysical Society XXV, NH014, pp.25-29 Nice France, April (2000).

[3] X. Tian, H. Yasukawa, T. Ideguchi, T. Okuda, S. Adachi and M. Hata, "A study on CORBA-based distributed observations system of seismic electro-magnetic wave". Proc. of 1999 International conference on Information Fusion, FUSION 99, 2, pp.841-846, July (1999).

[4] G. Kramer (ed.), "Auditory Display Sonification, Audification, and Auditory Interfaces", Addison Wesley Longman (1994).

[5] D. H. Brooks and R. S. MacLeod, "Electrical Imaging of the Heart", IEEE Signal Processing, 14(1) pp.24-42 (1997).

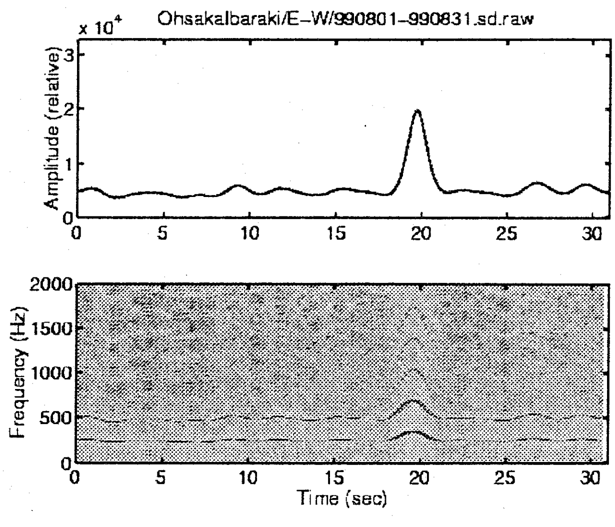

Fig. 2. Amplitude (upper) and spectrogram (lower)