A SIMPLE SIGNAL DETECTION METHOD FOR GREAT EARTHQUAKE PREDICTION BY OBSERAVATION OF SEISMIC ELECTROMAGNETIC WAVE RADIATIONS

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ABSTRACT

A new signal processing method for detecting electromagnetic radiation due to the earthquake activities are presented. The radiation is usually contaminated by background noises. In this paper, a simple method which deals with difference data between the latest data and averaged data. over past several years are proposed. The good performance was obtained to detect a precursor signal of an earthquake by utilizing the proposed method.

1. INTRODUCTION

Recently, a lot of methodologies have been investigated to find a provability of prediction for earthquake.[1]-[3], [6]-[8]. Eelectromagnetic wave due to seismic activities can be radiated as an indication of an earthquake. The radiation is considered to originate in electro-mechanical 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. A possibility is given by detecting the radiation 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 223 Hz frequency in extremely low frequency (ELF) band [2], [3].

Fig. 1 shows the relationships between electromagnetic radiation in the frequency 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, background noise caused by atmospheric discharges in the tropical regions is increased. Signal detection in ELF band resulted in a most possibility for obtaining the signal to noise power ratio. The 223 Hz is also chosen as a prime factor, not to be a multiple of the frequency of the power supply, that is 50 or 60 Hz.

The seismic radiation is still accompanied by a background noise caused by atmospheric discharges in the tropical regions in spite of the deliberate selection of the observed frequency. 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 longer 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. We developed a signal processing method that is able to discriminate the seismic radiation from the background noise [6]. It also discussed the auditory display facilitates searching anomalous seismic radiation immediately, which leads us to predict an occurrence of an earthquake[4], [5].

The previous study [7] reported that a combination of band-pass filtering and all-pass differentiation was effectively utilized to detect precursor signals of an earthquake. In this paper, we propose a simple method for signal processing on considering the performance of signal detection.

2. SIGNAL PROCESSING FOR PRECUSOR DETECTION

Fig. 2 shows a block diagram of observation station. Electromagnetic waves in ELF band are received by tri-axes loop antennas, followed narrow band band-pass filtering with 1 Hz window. Received data are collected via frequency converter, band pass amplifier and analog-to-digital converter to a data logger. Collected data in the data logger are sent every day to a center station through a telephone network.

A conventional method previously proposed [6] is presented. Let us introduce an example of the signal processing. A signal detected by an observation station in Ibaraki Osaka in July and in August '99 is shown in Fig. 3. 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.

In order to extract the seismic radiation, the low frequency (LF) component with frequency smaller than 8 cycle/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.

In Fig.3, thick lines 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 magnitude is; however, comparable with other peaks like that observed in July 5. The seismic activity extracted through the above process is more promising for the earthquake prediction than the LF component of the original signal.

3. PROPOSED METHOD

In this section, we propose a simple method for signal processing the received data in order to detect the seismic radiation. In addition to conventional processing method, we introduce the idea of synchronous averaging methodology. Using this scheme, the trends in every years which are summed up and averaged can be rejected. Examples are shown in Fig.4 to Fig.6. The received data are observed between September and October in 1998 to 2001. An earthquake with M5.5 occurred in North part in Wakayama Prefecture on August 21st in 1999. The seismic activity is also observed at Ibaraki city in Osaka Prefecture over few days August 21st in 1999.

Fig.4 (a) (upper line) shows received signal observed at Ibaraki city in Osaka Prefecture over two months until August 21st in 1999. Fig.4 (b) shows results by means of conventional band-pass filtering method. The precursor can be observed before earthquake occurred. Fig.5 (a) (upper line) shows synchronous averaged data observed at Ibaraki city in Osaka Prefecture over two months until August 21st in 1998, 2000 and 2001, in which periods great earthquake were not occurred. Fig.5 (b) shows synchronous averaged data for conventional band-pass filtering signal observed with same condition as mentioned above. Some noise components are little bit cancelled by synchronous averaging.

Fig.6 (a) shows the difference data between the received signal (Fig.4 (a)) and the synchronous averaged data (Fig. 5(a)). Fig.6 (b) also shows the difference data between the received signal (Fig.4 (b)) and the synchronous averaged data (Fig. 5(b)). In the figure, the precursor can be found easily, and noise components are rejected than the conventional method as shown in Fig.4 (b).

In the final camera ready version, we add discussion on further comparison with other alternatives and statistical analysis.

4. DISCUSSION

It is important to provide a visual display for alarm signal, conjunction with detections of the precursor of the great earthquake. We have proposed a sonification scheme suitable for these kind of systems [6]. For auditory 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.

Furthermore, we have been investigating the relationships between the observed electromagnetic wave in the ELF band and the date and place of earthquake occurrence. Then we are studying a system which can automatically verify the relations between the data base of the observed electromagnetic wave in the ELF band and the date and place of earthquake occurrence by the input data of the actual earthquake occurrence.

5. CONCLUSIONS

A new simple signal processing method using the difference for past averaged data was proposed to discriminate the earthquake activity from the background noise in the observed electromagnetic wave in the ELF band. The actual examples of the analysis show that the proposed method has a probability of an advantage for detecting the prediction. In order to confirm the output without prediction error, statistical analysis for other collected data is required. It is one of the future problems.

ACKOWLEDGMENT

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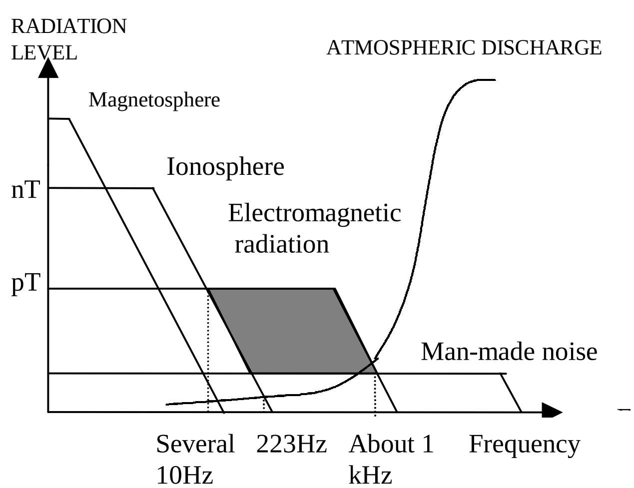


Fig. 1. Relationships between Electromagnetic Radiation Level and Observation Frequency

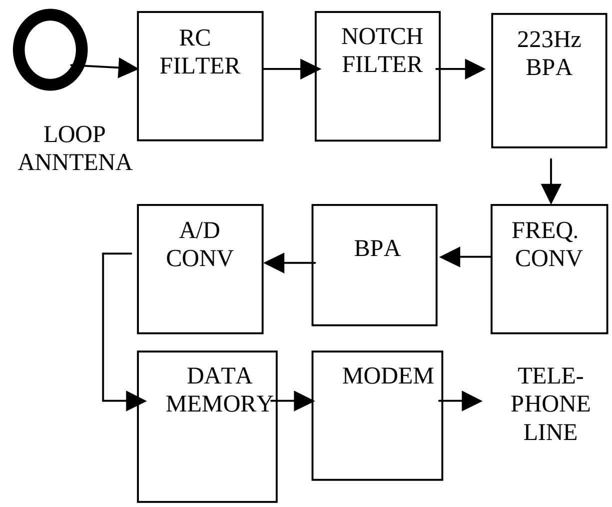


Fig. 2. A block diagram of Observation Station

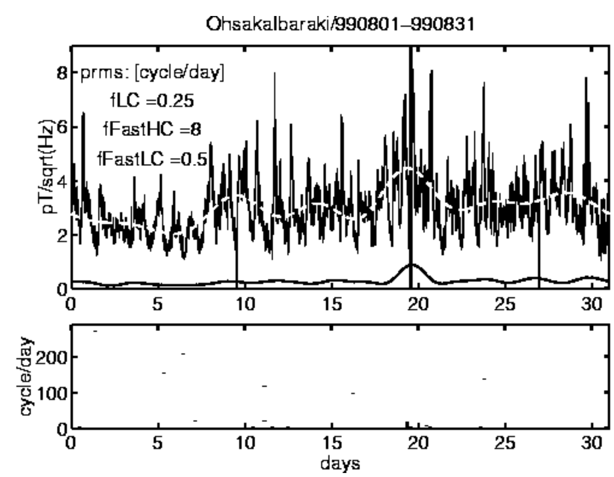
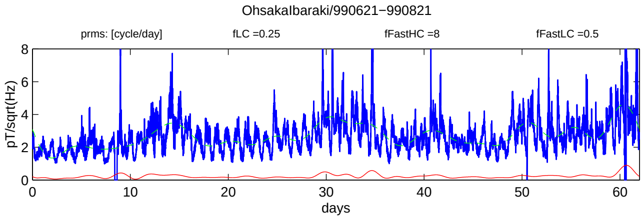
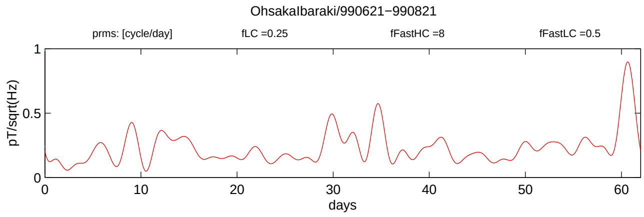


Fig. 3. A signal detected at an observation station in Ibaraki Osaka (thin line), the low frequency component of the signal (dashed line), and that of the amplitude of the fast oscillating component of the original signal. Observations were made 1st to 31st of August ’99.

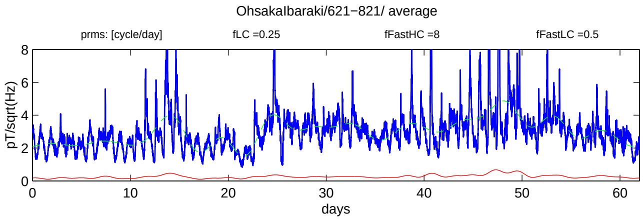


(a) Received signal (upper line) observed at Ibaraki city in Osaka Prefecture over two months until August 21^{st} in 1999.

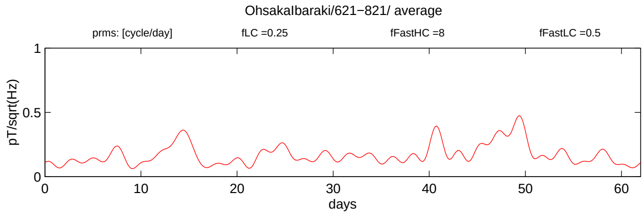


(b) Filterd data by means of conventional band-pass filtering method.

Fig.4.

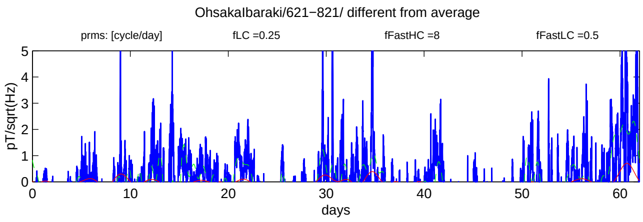


(a) Synchronous averaged data (upper line) observed at Ibaraki city in Osaka Prefecture over two months until August 21^{st} in 1998, 2000 and 2001.

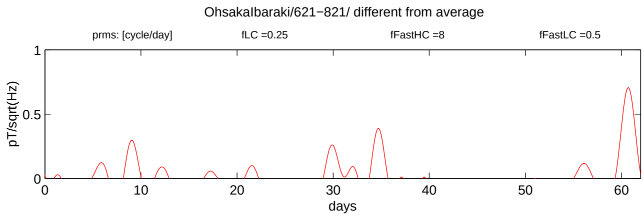


(b) Synchronous averaged data for conventional band-pass filtering signal observed with same condition as (a).

Fig.5.



(a) Difference data between the received signal (Fig. 4(a)) and the synchronous averaged data (Fig. 5(a)).



(b) Difference data between the filtered signal (Fig. 4(b)) and the synchronous averaged data (Fig. 5(b)).

Fig.6.