

## Detections of electromagnetic pulses excited by earthquakes

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In order to find electromagnetic (EM) pulses which would be generated due to piezo-electric effect by strong stress impacts to the earth crust when the earthquakes occurred, we have been observing EM pluses using tri-axial electromagnetic sensors installed in a deep borehole (100 m in depth) and on the ground. Detected EM noise has been analyzed on real-time basis by personal computers by means of two methods, one was a continuous display of frequency dynamic spectra ( $f-t$  diagram) in a range from 0 to few kHz for monitoring EM environments in the earth, and another was to estimate arrival direction of EM pulses.

So far, we have detected many EM pulses in the frequency range mainly around few kHz, and have analyzed their waveforms. Almost all of wave polarizations and distant decay rates in the earth have shown clear properties of lightning EM pulses. Therefore, at this stage, we could not detected EM pulses related to earthquakes.

We found the reason why we could not detected EM pulses excited by earthquakes. The reason was wave energy loss during their propagations in the earth due to high electrical conductivity of the earth medium. One of the parameters of wave decay is given by Skin Depth of the earth medium as a function of the EM wave frequency. The Skin Depth is a characteristic distance which is inversely proportional to square root of wave frequency  $f$ . Therefore it was expected that extremely low frequency component of the EM pulse excited by earthquakes can propagate for a long distance in the earth. Therefore, we adapted the  $f-t$  diagram system to monitor the frequency range  $0 \sim 25$  Hz, and started its continuous monitoring from December, 2011.

During the period from Dec. 20, 2011 to Jan. 24, 2013, we detected ten EM pulses surely related to earthquakes among thirteen ones with magnitude greater than  $M 2$  occurred within an area of radius of 40 km centered at the EM observation site. We confirmed that the detected EM pulses were excited by the piezo-electric effect due to stress impact into the earth crust. Now we are going to clarify the time relation between waveforms of seismic waves and of their related EM pulses.

Keywords: electromagnetic pulses in the earth, detections in boreholes, relation with earthquakes