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Radiations of earthquake-excited electromagnetic waves from the ground

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We have been observing electromagnetic (EM) pluses excited by earthquakes, using tri-axial electromagnetic sensor system installed in a borehole of 100 m in depth in the campus of Kyoto Sangyo University. During the period of 13 months from December 20, 2011 to March 26, 2013, we had nineteen earthquakes with magnitude of M>2 occurred around our EM observation site. They were within a circle of radius of 40 km centered at the EM observation site. We have confirmed detections of clear EM pulses for thirteen earthquakes among them. Seismic intensities at the EM observation site by these earthquakes were mostly 1 or less. From March, 2013, we added EM measurement above the ground. Furthermore, we began to capture waveforms of EM pulses in the borehole and above the ground and of seismic waves installed near the borehole simultaneously. Then we have confirmed that the detected EM waves were co-seismic ones readily generated by piezo-electric effect in earth's crusts [1].

Figure 1(a) shows a waveform of seismic wave detected at the EM observation site when an earthquake of M3.0 occurred at 10 km depth and at 5.4 km north of the EM observation site at 03:57 Dec. 2013, and (b) shows a waveform of magnetic H_{ew} components of the EM pulse detected in the borehole. Figure 1(c) also shows a waveform of H_{ew} component of the EM pulses detected above the ground where is on a hill of 60 m at about 600 m south-east of the EM observation site, in which the waveform have delayed 0.257 sec from that measured in the borehole. Therefore, this result shows clear evidence that earthquake-excited EM pulse has been radiated from the ground. We had another evidence of EM pulse radiation out of the ground surface when a large earthquake (M6.3) occurred at 14.8 km depth and at 130 km south-west of the EM observation site, in which earthquake-excited EM pulse was detected above the ground of the EM observation site in the campus. In that case, EM pulse was detected above the ground at 13.063 sec prior the detection in the borehole.

Next step is to detect and confirm EM pulses radiated at the occurrence of earthquakes. The final destination is to detect EM pulses radiated before earthquakes. For these purposes, we need to accomplish measurements of EM pulses in deeper earth (at about 1 km depth) after improving the sensitivity of the EM sensors.

[1] M. Tsutsui, submitted to IEEE Geoscience, Letters, 2014.

Keywords: seismic wave, electromagnetic wave, observations above and under ground, EM wave radiation from the ground

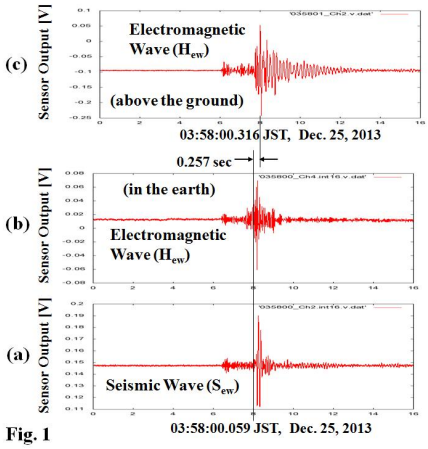

Fig. 1