Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

SEM22-08 Room:301A Time:May 25 11:00-11:15

Characteristics of vertical electric fields derived from borehole measurements in association with an earthquake

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We have shown many examples of electric fields associated with natural and artificial earthquakes, but they are all horizontal components and no information has been derived for the vertical component. In theoretical arguments, the vertical electric field should vanish at the surface of the Earth and hence surface measurements are unlikely to be significant. We therefore attempted to measure vertical electric fields using a borehole casing pipe as an electrode with a surface coil surrounding the borehole at the Earth's surface. In fact, Takahashi and Fujinawa established such a measurement system for two boreholes in the Boso peninsula and we used this system for our measurements. At one site, the borehole length is 803 m and at the other site it is 106 m. Both sites are equipped with electrodes at the surface for measurements of two horizontal components of electric field. The electrode span ranges from 9 m to 36 m. Both sites are located in electrically noisy environments and precise measurements of electric field turned out to be almost impossible. Nonetheless, fairly clear signals could be observed for the main ground motion of an earthquake of magnitude 7.0 which occurred in the vicinity of Torishima on January 1, 2012. In the deep borehole case, the magnitude of vertical electric field is half of that of horizontal electric field, whereas in the shallow case the vertical electric field is one order of magnitude smaller than the horizontal electric field. This is quite understandable in view of the expectation that the vertical electric field should be smaller and smaller towards the surface of the Earth. This result indicates that seismic dynamo effect signals can be detected by borehole measurements. The theory of seismic dynamo effect predicts that the resonance between the seismic velocity and ions motion in groundwater at depth should occur at the cyclotron frequency corresponding to the total magnetic field. This should be verified through the transfer function of electric field to seismic velocity. We finally point out that clearer electric-field signals would be observed if measurements are made at the bottom of deep borehole and the detection of seismic wave there in terms of electric field would become possible well before the arrival of seismic wave at the surface of the Earth.

Keywords: seismic dynamo effect, electric field, seismic wave, borehole