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Three dimensional arrival directions of electromagnetic pulses in the earth

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In order to confirm electromagnetic (EM) pulses which might be generated by strong stress impacts to the earth crust when the earthquakes occurred, we have been observing them by a sensor system inserted into a borehole of 100 m in depth in the campus of Kyoto Sangyo University. Although we also have been trying to detect earth-origin EM pulses and to identify their source locations on real-time basis by an observation network with two or three sites, we could not find them yet.

At one of observation sites, we installed two magnetic sensor systems at 95 m-depth in a borehole and on the ground. We detected EM pulses and examined differences of amplitude and phase between their waveforms. We clearly confirmed that amplitude of vertically incident EM pulses were strongly depressed, and that their phases at the bottom of the borehole were largely delayed. We estimated electrical parameter of the medium in the sedimentary layer such as the electrical conductivity, the skin depth for a VLF signal, and its propagation velocity in the medium.

On the other hand, we detected EM pulses with small amplitude of magnetic field and with one or two cycles which were different from lightning generated ones. We tried to determine their propagation directions, up- or down-ward, from phase differences between waveforms of a horizontal magnetic field component of EM pulse simultaneously detected at the 95 m-depth in the borehole and on the ground. Some of their waveforms indicated clear differences between their phases, suggesting down- or up-ward propagations. However, others could not be distinguish their propagation directions, because their waveforms did not show conformity with each other. We found a reason from behaviors magnetic field vectors at the vertically different two detecting points. Almost all of EM pulses detected in the earth indicated ellipsoidal polarizations whereas most EM pulses detected on the ground indicated linear polarizations. We have recognized that we have to use Poynting vectors of EM pulses detected in the earth and have to determine their arrival directions. For this purpose, it was needed to develop a new sensor system composed of tri-axial electric and magnetic sensors.

Manufacturing a tri-axial electric dipole antenna system was another hard subject, because we cannot secure wide space for the deployment of horizontal dipole elements in the narrow borehole. For solving this problem, we have been developing horizontal antenna having enough gain equivalent to that of usual long horizontal antenna. At the present stage, we can not introduce the details of the tri-axial electric dipole antenna, because we are applying for a patent for this new sensor system, we would be able to show it at the symposium.

Keywords: electromagnetic pulses, propagation in the earth, detection of arrival direction, development of detection system