Signal Discrimination of ULF Electromagnetic Data with the Use of Interstation Transfer Function and Continuous Wavelet Transform

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Electromagnetic phenomena are recently considered as a promising candidate for the short-term prediction of large earthquakes. There have been accumulated observational reports in a very wide frequency range. Among the various observational methods, one of the most promising methods is the ULF (f ~10 Hz) electromagnetic measurement on the ground because of the sufficient skin depth. The observed ULF data are superposition of some possible signals. The first one is the external source field associated with the solar-terrestrial activities such as the geomagnetic pulsation, geomagnetic storms, and substorms, and their inductive field. The second one is the regional artificial noises which are mainly associated with the operation of the DC driven trains and factories. The last one is the more local signals around the magnetometer such as movement of the magnetic objects, mechanical vibration of the ground, and inner circuit noises. The signal associated with the crustal activity is generally very weak, so that the problem is how to discriminate from other noises. We try to eliminate the global geomagnetic field and their inductive electromagnetic field in the period of a few second to 1,000 seconds from the observed electric and magnetic data.

In this aim, the interstation transfer function (ISTF) approach are applied, and the data obtained at the Kakioka Magnetic Observatory, JMA are used as the remote reference. Once the ISTF could be estimated appropriately and assumed to be time invariant, the estimation of global electromagnetic field (less artificial noises) at ULF magnetic station will be possible. Therefore, we can consider that the differences from the observed data does not include any global electromagnetic field. We applied the interstation method to the electromagnetic transfer functions (MT impedance) in the same way.

We used the continuous wavelet transform instead of the traditional Fourier transform in the whole processes of signal discrimination because of its superiority in the sufficient time-frequency resolution of the signals. For this aim, we formulated the generalized time-scale (frequency) transfer functions in wavelet domain. The Morlet wavelet is used as the mother wavelet in this study. By using the wavelet transform, the calculation of the time-frequency distribution of the correlation functions between input and output components of the linear system becomes possible, therefore, the accuracy of the transfer function estimation could be improved with the use of coherent subsections.

The proposed method has been applied to the electric and magnetic data observed at the ULF electromagnetic sensor array in the Boso Peninsula, Japan. The accuracy of the estimated transfer functions are quite well in the range of a few second to 1,000 seconds. In order to verify the possibility of the global electromagnetic field reduction, the proposed method has been applied to the data for the interval of the geomagnetic pulsations and geomagnetic storms turned up, and geomagnetic quiet day. The results indicate that the almost whole of such global signals could be eliminated sufficiently. This imply that the discrimination of desired electromagnetic phenomena will be possible regardless of the geomagnetic activities.