Array analysis in subsurface monitoring using seismic ACROSS: (2) Evaluating the effect of small-scale heterogeneity

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The Accurately Controlled Routinely Operated Signal System (ACROSS) is an effective tool for active monitoring of subsurface geophysical properties. Seismic ACROSS provides us with continuous record of transfer function between the transmitter and the receiver, which is interpreted as the tensor Green's function sampled at finite discrete frequencies.

Hasada et al. (2006 AGU Fall Meeting) reported that there are significant frequency dependence in the transfer function acquired by seismic ACROSS and suggested that the frequency dependence may be caused by multipath arising from heterogeneous structure of propagating medium rather than material dispersion.

In order to interpret the mechanisms and locate the structure causing the frequency dependence, we have analyzed the ACROSS transfer functions observed at several seismic stations including borehole seismometers and a surface seismic array. First we draw spectrograms from the observed transfer functions and notice some conspicuous patterns in both of P and S wave packets. Location of the structure causing each spectral pattern can be (1) near the transmitter, (2) on the propagation path, or (3) near the receiver. In the case 1, the spectral pattern should appear in the data observed at all stations. Utilizing the data acquired by seismic array enables us to distinguish the case 2 or 3, though there is difficulty due to limited distribution of receivers.

For example, we take notice at the significant spectral peak lies around 16Hz in the P wave observed by the seismic ACROSS transmitter at Toki and the receiver at ~60km southeast of the transmitter. The similar feature is found in the data from another station at ~10km north of the transmitter, indicating that the location of the structure causing 16Hz peak of P wave is expected to be near the transmitter.

On the other hands, spatial correlation of the transfer function observed by the seismic array indicates the effect of small-scale heterogeneity. By slant-stacking of the array data, we have been able to remove the effect of small-scale heterogeneity and recover the incident plane wave successfully. The residuals obtained by the least-square fitting of the array data to the estimated incident plane wave can be considered to consist of the scattered waves from the heterogeneous structure.

Furthermore, we have attempted to develop the method to reduce the effect of intermediate-scale heterogeneity, whose spatial scale is larger than the array interval, by means of staking of noise power spectrum and cross spectrum. This procedure may help us to eliminate the temporal changes associated by the changes of the local environment.