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Geophysical Exploration with Seismic Interferometry-Application to Cross-hole Tomography

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Seismic interferometry is the process of generating new seismic responses by cross-correlation seismic observations at different receiver locations. Applying seismic interferometry to underground plural receivers can synthesize a virtual source at the receiver location. In 2004, this method was proposed by Bakulin and Calvert. They indicated that it could prevent the influence on a medium with complex overburden in near-surface area for imaging the deeper structures. In this study, we performed numerical simulation and cross-hole experiments in order to examine the validity of virtual source method.

Numerical simulation was performed with a second-order accurate time, fourth-order accurate space, and 2-D staggered-grid finite-difference method (100cm in length, 170cm in width and Vp = 2000m/s, Vs = 1000m/s). The top of the left in this area was determined to be a coordinate origin. Borehole-1 was set at x=65cm and borehole-2 at x=105cm. Eight receivers on each borehole are set at intervals of 10cm from z=2cm to 72cm. Ricker wavelet (peak frequency:2000Hz) was used as a source function , and 161 shots were hit sequentially at intervals of 1cm from x=5cm to 165cm on the top. Cross-correlation processings were performed to all receiver records, and summation processings were performed to all cross-correlation results. Thus, a VS was synthesized at the receiver location, and the wave field propagated from VS to other receivers was recorded.

To confirm that these results using the VS method were effective, we performed the other simulation under the different condition. Sources were in the borehole-1 and receivers were at the same positions of the VS simulation. In the second situation, we acquired the similar results with the wave propagation of the VS simulation. In conclusion, the effectiveness of VS method for cross-hole tomography is confirmed.

And then, we performed model experiments on the similar conditions of the simulations. A homogeneous vinyl chloride board was used (100cm in length, 170cm in width, 2cm in thickness and Vp=1990m/s, Vs=980m/s). Borehole-1 was set at x=65cm and borehole-2 was set at x=105cm. Eight receivers on each borehole are set at intervals of 10cm from z=2cm to 72cm. We hit the top of the board 33 times moving 5cm intervals from x=5cm to 165cm. Processing similarly with the numerical simulation, VS was synthesized at the receiver location, and VS emitted the wave to the other receivers.

Like the numerical simulation, we performed the other experiment. The position of the VS was directly hit, and wave propagation was recorded at each receiver. In the cross-hole experiments, we confirmed that the VS method is valid for cross-hole tomography.

This study shows the results of our experiments in the laboratory and simulations, which are aimed to synthesized the tomography data virtually measured between cross-holes by using the VS method. The processing is applied to the cross-correlation to the seismic waves generated from the ground surface and measured with plural receivers set in two boreholes. In the results, we successfully synthesized the new records, which can be clearly picked up the positions of first motions of waves. This result indicates the validity of the VS method for applying the geotomography. In the next stage, we will try experiments and simulations on the more complex models and measure the field data for improving the practicality of this method.