A new method to determine phase velocities of Love waves using microtremor records from a double-circular seismic array (Part 1)

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Microtremor exploration is a generic term for methods to evaluate phase velocities of surface waves by analyzing microtremor records that are obtained with seismic sensors placed on the ground surface, and thereby to estimate the underground seismic velocity structures in an indirect way. Among the most popularly used tools for this purpose is the spatial auto-correlation (SPAC) method, which consists in simultaneously measuring microtremors with an array of seismic sensors placed at different locations around a circumference plus another at its center, and analyzing the seismograms to obtain estimates for the phase velocity dispersion curves for the fundamental-mode surface waves. The method usually deals with Rayleigh waves.

Surface waves are made up of Rayleigh waves and Love waves. The procedure to estimate phase velocities of Love waves by seismic-array exploration of microtremors is much more complicated than in the case of Rayleigh waves, so only in a few cases have the phase velocities of Love waves been actually evaluated in previous literature. Also, existing analysis theories either require the phase velocities of Rayleigh waves to be known beforehand or allow the phase velocities of Love waves to be evaluated only simultaneously with those of Rayleigh waves, so the accuracy and stability of estimation for the phase velocities of Love waves in fact depend on the accuracy of estimation for the phase velocities of Rayleigh waves, a weakness inherent in the method.

We have reinterpreted the SPAC method from an original viewpoint, and have expanded it to build up a comprehensive and generic theory that integrates the whole family of relevant approaches to evaluate phase velocities of surface waves from microtremor seismograms by way of intermediary quantities called 'spectral ratios.' At each time instant, the set of records are expanded in a Fourier series with respect to azimuth, so that we obtain a set of Fourier coefficients that are represented in the form of complex time histories. We then estimate power- and cross-spectral densities of those Fourier coefficients. The spectral densities, thus obtained, generally contain information on the phase velocities, powers, and arrival directions of individual modes of Rayleigh and Love waves. By taking the quotient of two different sorts of such spectral densities, we can cancel out information on their powers and arrival directions, and extract information on their phase velocities alone.

As part of this work, we would like to propose, with special emphasis, a new algorithm that enables to estimate phase velocities of Love waves directly by using horizontal-motion records of microtremors alone, even when the phase velocities of Rayleigh waves are not known beforehand. The method requires horizontal-component seismograms of microtremors, obtained with seismic sensors placed around two circumferences of different radii, but does not require seismograms obtained at the center of the circles. If their new method makes it possible to accurately evaluate the phase velocities of Love waves besides those of Rayleigh waves, that is expected to constitute a significant contribution to the development of microtremor exploration theories, since that adds a new constraint on the underground structure under examination.