修士論文

Study on Vector-Wave Envelopes in von Karman-Type Random Media
フォン・カルマン型ランダム媒質における ベクトル波エンベロープに関する研究

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要旨

The source duration time of earthquake rupture is short; however, the apparent duration time of recorded high-frequency seismogram at a long distance is much larger than the source duration time. This phenomenon is called envelope broadening, which is caused by scattering due to the random velocity inhomogeneity in the solid earth medium.

For P-waves, the excitation of the transverse component amplitude is also scattering contribution due to the random velocity inhomogeneity. Some observations show that these phenomena are frequency dependent. When the wavelength is shorter than the characteristic scale of random media, the Markov approximation is known to be a powerful statistical method to simulate directly vector-wave envelopes in random elastic media for the incidence of an impulsive plane wavelet. The Markov approximation is a stochastic extension of the phase screen method. The vector-wave synthesis was successfully formulated only for random media characterized by a Gaussian autocorrelation function (ACF). The synthesized P-wave envelopes well show both envelope broadening and the excitation of transverse component amplitude, but they are frequency independent.

In order to explain the frequency dependent characteristics of seismogram envelopes observed, it is necessary to formulate the synthesis of vector-waves in random media characterized by a von Karman-type ACF. The corresponding power spectral density function (PSDF) obeys a power-law for large wave-numbers, where parameter κ controls the role-off of the spectrum at large wavenumbers. Improving the numerical integration method, we simulate vector-wave envelopes: the excitation of the transverse component and the broadening of both the longitudinal and transverse component envelopes increase with travel distance increasing. The peak ratio of the transverse component envelope to the three-component sum envelope increases with travel distance increasing. Envelopes in von Karman-type random media with $\kappa = 1.0$ are frequency independent; however, the frequency dependence becomes apparent as the κ-value becomes smaller, that is, the PSDF of the velocity fractional fluctuation becomes rich in short wavelength components. Envelopes for the incidence of a plane S-wavelet are also synthesized. The envelope broadening of S-wavelet is larger than that of P-wavelet at a given frequency for the same fractional velocity fluctuation.

The partition of P-wave energy into the transverse component is a good measure of lithospheric inhomogeneity. We have analyzed stacked teleseismic P-wave envelopes of deep earthquakes by using the synthesized envelopes. Supposing the thickness of the lithosphere to be 100 km, the average P-wave velocity to be 7.8 km/s and the correlation distance to be 10 km, we estimated von Karman-type parameters statistically characterizing the lithospheric inhomogeneity from the peak ratio of the transverse component envelope to the three-component sum envelope: the active group has the RMS fractional velocity fluctuation $\varepsilon = 0.05$ and $\kappa = 0.2$; the stable group has $\varepsilon = 0.02$ and $\kappa = 0.3$.

We have successfully simulated vector-wave envelopes in von Karman-type random media; however, random media have been confined to isotropic and homogeneous. It will be necessary to study the contribution of non-isotropic randomness, nonuniform randomness, and the existence of ground free surface for the synthesis of vector-wave envelopes.