Synthesis of Scalar Wavelet Intensity Propagating through Random Media Having Power-Law Spectrum

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Observed short-period seismograms of small earthquakes show envelope broadening of an S-wavelet and excitation of long lasting coda waves although the source duration is very short. Those phenomena are interpreted as result of scattering by earth medium heterogeneities. As a mathematical model, we study the propagation of a scalar wavelet through von Karman-type random media. When the center wavenumber of the wavelet is lower than the corner wavenumber, we are able to synthesize wave intensity by using the radiative transfer equation with the Born approximation. When the center wavenumber is in the power-law spectral range higher than the corner wavenumber, we can synthesize intensity time traces by using the Markov approximation method based on the parabolic/paraxial approximation. This method is effective for the intensity synthesis especially near around the peak arrival; however, it fails to synthesize coda excitation due to wide-angle scattering. Here, developing the scheme given by (Sato, 2016), we newly propose the following method for the synthesis of intensity time trace from the onset through the peak until coda: (1) We divide the random medium spectrum into the high–wavenumber (short-scale) and the low-wavenumber (long-scale) spectrum components by using the center wavenumber of the wavelet as a reference. (2) Applying the Born approximation to the short-scale component of random media, we calculate the scattering coefficient. Substituting the scattering coefficient into the radiative transfer equation with a constant velocity, we calculate the intensity by using the Monte Carlo simulation. (3) Applying the Markov approximation to the long-scale component of random media, we analytically calculate the envelope broadening and wandering factors. (4) We convolve these factors with the intensity calculated in step (2) in the time domain, which leads to the Green function in the random media. As a test, we have compared intensity time traces derived from the above method and the FD simulation method for a Ricker source wavelet radiated from a point source in random media. We have confirmed good coincidence between them from the onset through the peak until early coda. The proposed method will be a theoretical basis for the study of random inhomogeneous velocity structure in the earth medium from mean square envelopes of short-period seismic waves of small earthquakes.

Keywords: scattering of seismic waves, Heterogeneous structure of the earth, wave theory

