Envelope broadening and scattering attenuation in random media having a power-law spectrum

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In short-period seismograms of small earthquakes, we see peak delay and envelope broadening of an S-wavelet with travel distance increasing. Those phenomena are results of scattering effect caused by random velocity inhomogeneities of the earth medium. As a simple mathematical model, we study how the envelope of a scalar wavelet varies in von Karman type random media, which have a power-law spectrum at large wavenumbers. Using the center wavenumber of a wavelet as a reference, we propose to divide the random medium spectra into the low-wavenumber spectral (long-scale) component and the high-wavenumber spectral (short-scale) component. For the wave propagation through the long-scale component of random media, we may apply the parabolic approximation to the wave equation. Using the Markov approximation, we statistically synthesize the mean-square (MS) envelope of a wavelet, which shows a delay of the maximum peak arrival from the onset and broadening of envelope duration. The resultant envelope duration increases according to the second power of travel distance. Wide angle scattering caused by the short-scale component of random media attenuates wave amplitude with travel distance increasing. We use the total scattering coefficient of the short-scale component as a measure of scattering attenuation per distance, which is well described by the Born approximation. Multiplying the exponential scattering attenuation factor by the MS envelope derived by the Markov approximation, we can synthesize the MS envelope reflecting all the spectral component of random media. When the spectral role-off is steep at large wavenumbers, the envelope broadening is small and frequency independent, and scattering attenuation is weak. When the spectral role-off is small, however, the envelope broadening is large and increases with frequency, and the scattering attenuation is strong and increases with frequency. The proposed envelope synthesis is fully analytic. It can be a theoretical basis for the evaluation of random inhomogeneities of the earth medium from the analysis of seismogram envelopes.
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