

Envelope synthesis of multiply-scattered three-component vector elastic waves based on the Monte Carlo simulation

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The scattering theory of seismic wave for the synthesis of coda waves (e.g., Sato, 1984; Yoshimoto et al., 1997) reveals the relation between the non-isotropic scattering patterns and stochastic feature of random inhomogeneity of the medium under the assumption of the weak-inhomogeneity. However, their envelope model is valid only for short lapse time because their models are based on the single scattering approximation. On the other hand, recent developments of radiative transfer theory enable us to synthesize multiply-scattered waves. Although it is difficult to solve the radiative transfer equation analytically, Monte Carlo simulations which synthesize coda envelopes through the stochastic behavior of many particles has been done incorporating non-isotropic scattering pattern derived from wave scattering theory (Margerin et al., 2000; Przybilla et al., 2006). Here we report the synthesis of three-component MS envelope incorporating the non-isotropic scattering expected from Born scattering theory based on the Direct Simulation Monte Carlo (DSMC) method (Yoshimoto, 2000).

Non-isotropic scattering pattern of S waves in a randomly inhomogeneous medium is characterized by the scattering coefficient (e.g., Sato and Fehler, 1998). Normalizing the scattering coefficient by its solid-angle integration, we define the distribution function of the scattering direction for the statistical treatment in the DSMC simulation. We can simulate the variables which obeys the distribution function by inverse function method by using uniform random numbers. However, in this case we can not represent the inverse function of distribution function of S-wave scattering analytically. Therefore we pre-calculate the distribution function at every 0.5 degree grid as an alternative to the inverse function. To trace scattered S-wave particle in the DSMC simulation, we need to trace the polarization angle information. An angle between polarization direction of S waves and SV wave direction is defined as a characteristic parameter of the polarization direction. Contributions to each of three components of one energy particle can be calculated from the polarization direction.

We perform the DSMC for isotropic SH source in randomly inhomogeneous medium. The exponential-type auto correlation function having the characteristic scale a of $ak=0.1$ is assumed, where k is wavenumber of S waves. We use 15 million energy packets for the simulation. At each time step, three-component MS envelopes are calculated by counting the number of particle in the spatial mesh. At a lapse time of mean free time, direct wave amplitude on the horizontal plane has strong anisotropy among components: x-component MS envelope is strong along y-axis direction and vice versa. This is because SH waves polarize in transverse direction. Although this anisotropy is expected even in a homogeneous medium, we observe weak vertical component coda waves that are generated by the scattering from SH to SV waves. We found that the difference of MS amplitude of x and y components rapidly decreases as lapse time increases due to the scattering. Polarization directions of S waves are randomized and MS envelopes of three components are equalized at large lapse time.