Attenuation of maximum amplitude of direct wave due to spatially non-uniform distribution of random inhomogeneities and absorption

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High-frequency seismic waves of microearthquakes are broadened and attenuated with travel distance increasing because of the random inhomogeneities near the ray-path. We have conducted analyses of the peak delay time, which is defined as the time lag from the direct-wave onset to the maximum amplitude arrival of its envelope, to investigate the spatial distribution of random inhomogeneities. Our analyses, for example, revealed that the regions beneath the Quaternary volcanoes contain strong inhomogeneities (e.g., Takahashi et al. 2007 JPGU Mtg.). These results imply that the strong inhomogeneities beneath the Quaternary volcanoes may be generated by the magma-diapir. However, we may need to investigate the spatial distribution of the intrinsic attenuation in order to discuss the details of the existence of magma-diapir. Previous approach to estimate the 3D attenuation structures cannot separate the scattering and the intrinsic attenuation. If we use the 3D distribution of random inhomogeneities estimated by the peak delay time analysis, it becomes possible to estimate an attenuation structure which does not contain the apparent attenuation due to multiple forward scattering. In this study, we define the Q-value as the attenuation factor without the effect of multiple forward scattering, and clarify the characteristics of the maximum amplitude attenuation due to random inhomogeneities and Q-value. We propose an analytical method to calculate the maximum amplitude of root mean square (RMS) envelope in spatially non-uniform random media.

Seismic envelopes are numerically calculated by using the stochastic ray-path method (e.g., Sato and Korn 2007). This method defines the probability density function of wave scattering by the Markov approximation of parabolic wave equation, and simulates the intensity propagation by means of the Monte Carlo method. The medium is divided into thin spherical shells, and stochastic parameters characterizing the power spectral density function (PSDF) of random inhomogeneities are given for each layer. In this study, we add the exponential attenuation term due to Q-value for intensity particles. The PSDF of random inhomogeneities are assumed to be von Karman type. If we assume the spatially uniform random media characterized by von Karman type PSDF, the maximum amplitude of RMS envelopes decreases in proportion to the travel distance to the power of 2.0 ~2.7. The power depends on the spectral decay in short wavelength (Saito et al. 2002).

If the random inhomogeneities changes along the ray-path and $Q^{-1}=0$, the exponent of the travel distance dependence is affected by all of the stochastic parameters of the medium in which waves propagated. This characteristic is similar to the peak delay time. We modified the recursive formula (Takahashi et al. G.J.I. in press) for the maximum amplitude. This method can be applied to predict the maximum amplitude for the case that random inhomogeneities are smoothly distributed in the space. If we consider the finite value of Q, the maximum amplitude cannot be predicted by the maximum amplitude without the correction term due to the peak delay. In other word, we have to consider the increment of the travel distance due to the increase of the peak delay time.

Consequently, we can predict the maximum amplitude analytically assuming the spatially non-uniform distribution for both the random inhomogeneities and the attenuation. Our approach makes us possible to investigate the spatial distribution of the attenuation factor which does not include the effect of multiple forward scattering. If we apply this method of the observed data, the estimated Q-values contain the intrinsic attenuation and the apparent attenuation due to wide-angle scattering. By evaluating the Q-value for the backward scattering from the PSDF of random inhomogeneities, we may be able to discuss the spatial distribution of the intrinsic attenuation.