SH coda wave envelopes in 2-D media with cavities

Jun Kawahara[1], Kiyoshi Yomogida[2]

[1] Dept. Environmental Sciences, Ibaraki Univ., [2] Earth and Planetary Sci., Hokkaido Univ.

When one considers the scattering and envelopes of seismic waves in inhomogeneous media, physical models most popularly adopted may be random media and distributions of discrete scatterers such as cracks and cavities. Seismic wave envelopes in random media have been studied by many researchers. Saito et al. (2003), among others, simulated scalar waves propagating through 2-D random media using the finite difference method, and showed that the syntheses of the direct and coda wave envelopes are well described by the Markov approximation model and the radiative transfer theory, respectively. Concerning distributed cracks or cavities, the direct wave forms were shown to be well predicted by the single scattering theory, on the basis of 2-D SH (scalar) wave simulations by the boundary integral equation method (e.g., Kawahara et al., 2002). Yomogida and Benites (1995) also simulated SH coda waves excited by cavities and discussed their properties in terms of coda Q. There seems to be, however, no attempt to describe theoretically coda wave envelopes in media with discrete scatterers. In this study, we synthesized SH coda wave envelopes in 2-D media with circular cavities as Yomogida and Benites (1995) did, and then compared the results with the predictions by some existing models.

First, we randomly distributed cavities with the same size within a rectangular area, let plain Ricker wavelets (with the dominant frequency f0) incident on the bottom end of the area, and synthesized the seismograms at the observation points along the top end. Next, we calculated their RMS envelopes and then compared with some theoretical solutions. For the comparison, we adopted the single isotropic scattering model (hereafter, SISM; e.g., Sato and Fehler, 1997) and also the energy flux model (hereafter, EFM; Korn, 1990), that were modified to consider the geometry of the present experiments. SISM gives approximate solutions of the radiative transfer theory if multiple scattering is neglected, whereas EFM is a phenomenological model based on the empirical idea that the coda energy is uniformly distributed in space. The scattering coefficient, a parameter in SISM, was determined using the differential scattering cross section of a cavity for the scattering angle of 90 degrees, because the single wide-angle scattered waves should be dominant in the present experiments. The scattering Q required in both models was determined according to the single scattering theory on direct waves. Any parameters were calculated for the frequency f0.

We summarize the results as follows (Figure). (1) The envelopes by SISM agree well with the RMS coda envelopes for very small volume concentrations of the cavities, c. For somewhat larger c (say, about 1%), however, the agreement is restricted to portions just after the direct waves, and afterward the SISM envelopes decrease more rapidly. This tendency is more obvious for larger c. This suggests that the contribution of multiple scattering to coda waves is important even for fairly sparse cavity distributions, as was pointed out by Yomogida and Benites (1995). (2) The RMS coda envelopes recalculated using the single-scattered waves only are consistent with the SISM envelopes, as expected. (3) The envelopes by EFM generally agree with the RMS envelopes after some lapse times, showing a tendency in contrast to the SISM envelopes. The times when both envelopes begin to agree with each other vary with c and f0, but it is not clarified in this study how it depends on them.

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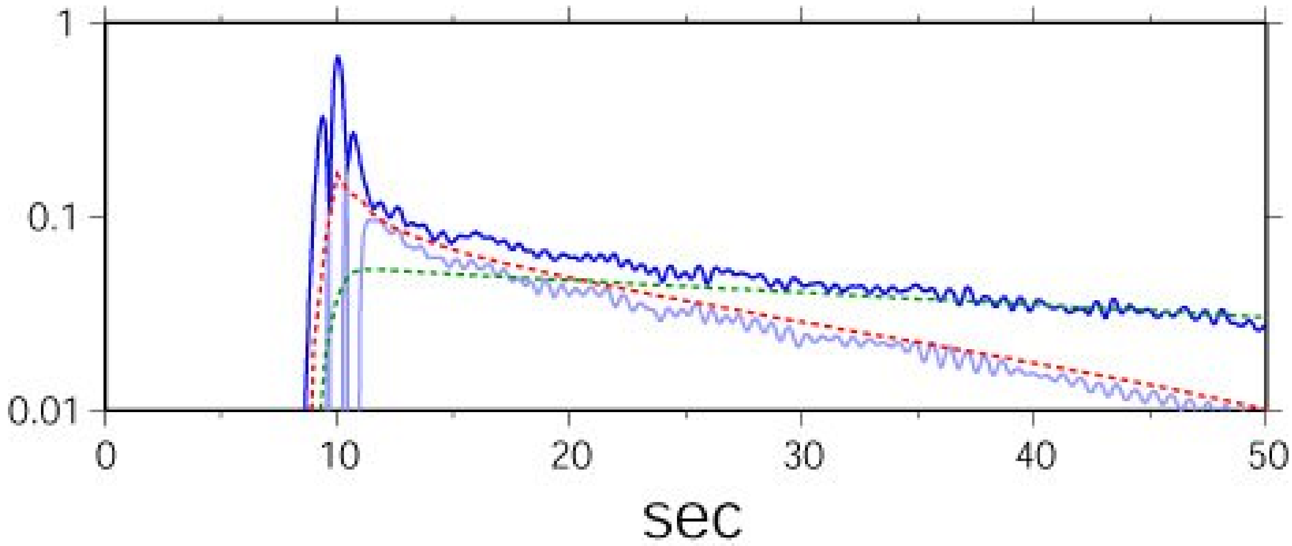

Figure.
Examples of SH wave envelopes (c = 1.6% and $f_0 = 0.3V_0/a$,
where a is the cavity radius and V_0 is the S wave velocity of the matrix).
Dark blue line: simulated RMS envelopes.
Light blue line: RMS envelopes composed of single-scattered waves only.
Red dotted line: envelopes by the single isotropic scattering model.
Green dotted line: envelopes by the energy flux model.