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Seismic spectroscopy using the transfer function obtained by ACROSS

Yoko Hasada[1]; Mineo Kumazawa[2]

[1] RSVD, Nagoya Univ.; [2] Geosci., Shizuoka Univ.

Observation by seismic ACROSS (Accurately Controlled Routinely Operated Signal System) provides us with a tensor transfer function (Green's function) between a transmitting site and a receiving site in a certain frequency range. Through some actual observation, we have found that the transfer functions generally have strong frequency dependences in the frequency range up to a few tens Hz. Our essential interest lies on where the frequency dependence arises. Some practical attempts have been examined to divide the transfer function into the parts that carry the information about the distinct regions along the path. One of the possible approaches is the positive use of the spectral feature itself as a key to identify its birthplace. The analysis of the spectral feature of the transfer function can be regarded as a kind of the seismic spectroscopy, which is useful to understand the structure in the target area, such as a resonator related to fluids.

If the transfer function has a peak in its amplitude, it can represent the existence of a resonator somewhere along the propagating path. However, the peak can also be made by the interference of only few wave arrivals. A resonance phenomenon is indeed caused by the interference of multiply reflected waves and there are no clear boundaries between two phenomena. Here we present the phenomenological representation of the typical transfer function involving each of resonance and interference, which can help us to recognize what actually happens on the propagating path of the ACROSS signal.

At first, we consider the simplest resonance phenomenon due to multiple reflection of the perpendicular incident wave between two parallel plains. The impulse response in such situation is composed of the pulse train with a constant interval. The transfer function is expected to have peaks in the amplitude and sharp changes in the phase, as typical characteristics of resonance phenomena. The resonance frequency is the reciprocal of the time interval if the reflection coefficients of the both boundaries are real and either positive or negative, where the sandwiched layer is low-velocity or high-velocity, respectively. In more general cases, the transfer function is controlled by two parameters R and T, where R is the product of two reflection coefficients and T is the two-way travel time in the sandwiched layer. Both R and T can be complex numbers. The phase angle of R represents the phase shift during reflection, while the imaginary part of T indicates the intrinsic attenuation.

As the simplest case of the interference, we consider the two arrivals in the impulse response. The Fourier transform of a time function with two pulses becomes a superposition of two complex sinusoids, whose amplitude fluctuates periodically in the same manner of beating in time domain. The interval of the amplitude peak in frequency domain is the reciprocal of the interval of the pulses in time domain. The remarkable feature of this transfer function is the presence of the sharp change in the phase at the frequency where the each valley of the amplitude locates.

The examples mentioned above are only two end members that can give rise to peaks in the transfer function. By comparing the spectral features of the transfer function with such typical characteristics of the simple model, the seismic spectroscopy can be realized, which may enables us to approach the phenomenon occurring in the target area.