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Green's Function Retrieval from the CCF of Random Waves and Energy Conservation for an Obstacle of Arbitrary Shape

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For imaging the earth structure, the cross-correlation function (CCF) of random waves as ambient noise or coda waves has been widely used for the estimation of the Green's function. Here we study the mathematics of the Green's function retrieval in relation to the energy conservation for a single obstacle of arbitrary shape. When an obstacle is placed in a 2-D homogeneous medium, the Green's function is written by a double series expansion using Hankel functions of the first kind which represent outgoing waves. When two receivers and the scattering obstacle are illuminated by uncorrelated noise sources randomly and uniformly distributed on a closed circle of a large radius surrounding them, the lag-time derivative of the CCF of random waves at the two receivers can be written by a convolution of the anti-symmetrized Green's function and the auto-correlation function of the noise source time function. We explicitly derive the constraint for the Hankel function expansion coefficients as the sufficient condition for the Green's function retrieval. We show that the constraint is equivalent to the generalized optical theorem derived from the energy conservation principle. Physical meaning of the generalized optical theorem becomes clear when the Hankel function expansion coefficients are transformed into scattering amplitudes in the framework of the conventional scattering theory.

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