The gap between theory and practice for seismic interferometry for the earth

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The field of seismic interferometry has grown spectacularly over recent years. Despite the flurry of theoretical derivations, the applications of this technique to passive data has mostly, but not exclusively, been limited to the retrieval of surface waves. Seismic interferometry is often justified using phrases such as "equipartitioning" and "time-reversal". These concepts are indeed important, but we often fail to verify to what degree these assumptions really hold for the earth. We review three formulations of seismic interferometry.

One formulation is based on a radiation boundary condition at a bounding surface. This theory requires only sources of field fluctuations at the boundary. For the earth, having sources near the surface is indeed most realistic, but the assumption of a radiation boundary condition is consistent with the surface of the earth being a stress-free. Alternatively one can consider an attenuating earth with a free surface. Theory predicts that noise generated by sources throughout the volume proportional to the attenuation, will produce the Green's function after cross-correlation. According to the fluctuation-dissipation theorem, such noise is indeed generated, but the magnitude of the thermal energy involved (kT) is much too small to be observable. Another derivation of Green's function is based on equipartitioning of normal modes. Since most noise is generated near the surface of the earth, the energy of earth's normal modes cannot be expected to be equipartitioned. But there is a more fundamental problem with this approach as well. If there is no attenuation, one can show that random sources with zero mean, lead to a linear growth of the energy in the modes, which violates the assumption of stationarity. If there is attenuation, the modes are strictly speaking not orthogonal and the theory also must be modified.

Observational studies of cross-correlation of noise typically lead to estimates of the Green's function in which the body waves are under-represented. This is likely to be caused by the inconsistency of the requirements of the conditions for Green's function extraction and the conditions in the earth.