Electromagnetic Green's function extraction by cross-correlation and deconvolution, with applications in hydrogeophysics

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We show that the two-point cross-correlation of electromagnetic field recordings is equal to the electric or magnetic earth impulse response between the two points. In lossless media this holds for uncorrelated sources located on a boundary. In general dissipative media, this holds under the condition that spatially and temporally uncorrelated noise sources exist throughout the volume. These sources should have a known amplitude spectrum and their correlated strengths should be proportional to the dissipative medium property function.

When the medium dissipates energy we show that the fluctuation-dissipation theorem can be applied. This directly leads to the desired noise sources, which have autocorrelations proportional to the dissipative part of the medium property functions, and with a proportionality factor equal to the thermal energy of the system. This implies that for systems in thermal equilibrium, thermal noise provides the desired sources to extract the Green's function. For systems in the linear regime of thermodynamic non-equilibrium, we conjecture that fluctuations in gradients can also lead to noise sources of interest. These gradients can be in temperature, acoustic pressure, or electrical and chemical potentials.

If multicomponent data are recorded in a plane with sources active on one side of the plane, the fields can be decomposed into two directional fields. They propagate, or decay, toward and away from the plane of receivers. The earth reflection response can be obtained by a deconvolution procedure using these directional fields.

We show examples for ground penetrating radar, diffusive electromagnetic fields and electric resistivity in hydrogeophysical applications.