Transport Coefficients, Entropy Production, and Fluctuation-Dissipation Relations in Electromagnetic Metrology from an Exact Projection-Operator Statistical-Mechanical Theory

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In this paper I develop exact transport relations and fluctuation-dissipation relations from a nonequilibrium projection-operator statistical-mechanical theory. Many high-frequency electromagnetic measurements are based on the relationships between dissipation and fluctuations. In nanotechnology, an understanding of fluctuations of thermal and electromagnetic energy and the effects of nonequilibrium are particularly important. The approach used here is based on the statistical-mechanical theories of Zwanzig and Robertson to produce exact expressions for transport coefficients and also a new entropy evolution equation. I develop an exact equation for entropy rate in terms of time correlations of the microscopic entropy production. This equation is an exact fluctuation-dissipation relation. We then define the entropy and its production in electromagnetic driving, both in the time and frequency domains, and apply this equation to dielectric and magnetic material measurements, cavity resonance, noise, and power. I apply this equation to study entropy fluctuation-dissipation equations for dielectric and magnetic susceptibilities, impedance and resonant systems, and measurements of Boltzmann's constant, and Johnson-Nyquist noise.