DIELECTRIC RELAXATION, SPECTRAL ENTROPY, AND EXTRACTION OF RELAXATION TIMES

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In this paper we study the relationship of time-dependent entropy and entropy production to dielectric measurements. The paper includes a discussion of the frequency-domain form of the entropy and its relationship to the permittivity, permeability, impedance, and dielectric measurements. An understanding of entropy and its evolution in electromagnetic interactions bridges the boundaries between electromagnetism and thermodynamics and is another diagnostic tool for characterizing high-frequency properties of materials. The approach used here is a Liouville-based statistical-mechanical theory. We show that the microscopic entropy is reversible and the macroscopic entropy satisfies a H-theorem. We derive new equations for the entropy and entropy production and apply them to functions of the polarization, magnetization, and macroscopic fields. We begin by proving a new, exact H-theorem for the entropy, progress to application of time-depedent entropy in electromagnetics, and then apply the theory to relevant applications in electromagnetics. The use of time-dependent entropy in the analysis of electromagnetic dielectric and magnetic interactions with materials has been isolated to a few applications. Much of the work performed to date has been limited to static and quasi-static analyzes that describe adiabatic demagnetization and depolarization. As electromagnetic measurements on the microscale become common place, it is important for theoretical understanding to keep pace. Knowledge of entropy and its evolution bridges the boundaries between electromagnetism and nonequilibrium thermodynamics. For static fields the electromagnetic interaction is modeled as action at a distance and the change in entropy occurs only through flow of heat into or out of the system. For nonequilibrium states the entropy changes due to relaxation.

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