Constitutive Relations

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Abstract

In order to provide a complete specification of electromagnetic field problems in complex mediums, the Maxwell equations must be supplemented with constitutive relations. These relations can be very general expressions between the involved electromagnetic fields: they may be linear or non–linear, homogeneous or nonhomogeneous, local or non–local in space and/or time; they may appear in differential, integral or algebraic form; they may be based on purely phenomenological argumentation, derived from fundamental underlying physical principles (rarely) or result as the outcome of more or less complicated homogenisation exercises.

For many years, theoretical and numerical approaches to electromagnetic field problems in complex mediums have essentially been speculative. Even in situations where reasonably convincing arguments were advanced why a specific type of medium should be described in such or such a way, frequently the relevant parameter ranges of the constitutive parameters were left unspecified.

Within the immediate past, however, significant progress in the materials sciences has brought many different varieties of complex mediums, very often in the form of composites, into the realm of actual existence. A consequence of that development is that studies investigating applicational/technological exploitation of novel materials is becoming a key driving force in complex mediums research.

This state of affairs provides the motivation to return to the very basis of theoretical investigations; the formulation of the constitutive relations which must provide the fundamental physical description of any complex medium. The emphasis of the presentation will be on *linear* materials which are denoted as *bianisotropic* in their most general form. A basic theoretical delineation of linear constitutive relations shall be followed by a detailed evaluation of the usefulness of many special forms of bianisotropic mediums (from uniaxial to biaxial types, from gyrotropic to Faraday chiral mediums, and beyond to the nonhomogeneous helicoidal bianisotropic mediums) in applicational studies.