A Comparison of Gyrotropic Bianisotropic Scalar Potential Formulations Under Vertical or Horizontal Biasing Conditions

Michael J. Havrilla*
Air Force Institute of Technology, WPAFB, OH 45433 USA

Research and analysis of gyrotropic materials has gained renewed interest in recent years, especially in nonreciprocal devices for nanophotonic applications. These materials can be utilized in creating and controlling unidirectional surface waves as well as maintaining preferential directions of radiation. Graphene has also found use in diverse applications (transistors, conductive ink, biosensors, etc.) due, in part, to their tunable nature via biasing fields and their ballistic transport properties. In the analysis of these types of material environments, Maxwell's equations are often directly employed using the six-vector formalism (Lindell, et al., Six-Vector Formalism in Electromagnetics of Bi-anisotropic Media). This methodology can accommodate generic bianisotropic media, however, inversion of a block 3x3 matrix is required, which can be algebraically tedious and can obscure physical insight. Under the simplifying case of gyrotropic bianisotropic media, a scalar potential formulation can be used to aid in analysis as well as provide deeper physical insight. The goal of this research is to develop and compare scalar potential formulations for gyrotropic bianisotropic media with vertical or horizontal biasing and to provide associated interfacial boundary conditions which are important for layered media applications.

The scalar potential formulations are developed by first decomposing Maxwell's equations into transverse and longitudinal relations with an assumed vertical or horizontal bias field. Next, a two-dimensional Helmholtz expansion of the transverse fields and currents into lamellar and rotational parts is performed. This decomposition leads to a block 1x1 matrix equation which offers considerable simplification and provides enhanced physical insight from the lamellar and rotational contributions. Boundary conditions at a gyrotropic bianisotropic material interface containing a graphene layer with vertical or horizontal biasing is derived. It is shown via comparison that biasing parallel to the material interface supports unidirectional surface waves, whereas perpendicular biasing does not support a surface wave mode spectrum which consequently limits certain device applications. Future work is also discussed.

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