Bianisotropic Scalar Potential Formulation with Biased Graphene Layer

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

Graphene layers are employed in diverse applications (transistors, conductive ink, biosensors, etc.) due, in part, to their tunable nature via biasing fields and their ballistic transport properties. In addition, gyrotropic materials can be employed to gain added control (such as non-reciprocal behavior) over surface (and radiation) modes. In the analysis of these types of complex media, Maxwell's equations are typically directly employed using, for example, the six-vector formalism (Lindell, et al., Six-Vector Formalism in Electromagnetics of Bi-anisotropic Media). Although this technique can handle generic bianisotropic media (i.e., fully populated material tensors), the drawback is that inversion of a block 3x3 matrix is required, which can be algebraically tedious and can obscure physical insight. However, if the material tensors take on a specialized gyrotropic bianisotropic form (which accommodates a large class of realizable materials), considerable simplification and physical insight can be gained via a scalar potential formulation. The goal of this research is to develop a scalar potential formulation for gyrotropic bianisotropic media and to additionally derive associated boundary conditions for a biased graphene layer located at a gyrotropic bianisotropic material interface.

The scalar potential formulation is developed by first decomposing Maxwell's equations into transverse and longitudinal relations for a gyrotropic bianisotropic material and then utilizing a two-dimensional Helmholtz expansion for the transverse fields and currents. It is shown that this approach leads to a 1x1 block matrix equation which offers considerable simplification in comparison to the block 3x3 matrix equation of the six-vector formalism. The 2D Helmholtz expansion has the added benefit of providing enhanced physical insight due to its inherent decomposition into transverse lamellar and rotational contributions. The analysis concludes with the derivation of boundary conditions at a gyrotropic bianisotropic material interface containing a biased graphene layer. Future work is also discussed.

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