GENERALIZED WAVEGUIDE THEORY INCLUDING ELECTROMAGNETIC DUALITY*

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Increasing interest in optical metamaterials, including for waveguides, has engendered the need for a theoretical framework that explicitly incorporates the electromagnetic properties of natural materials and metamaterials. Metamaterials expand the parameter space for electromagnetic phenomena such as negative magnetic susceptibility, which can be described by magnetic monopoles on a sufficiently large length scale. Although magnetic monopoles are not known to exist, they are theoretically permitted and serve as a valuable mathematical tool.

We employ the concept of magnetic monopoles to extend the Drude-Lorentz model for the electromagnetic responses of the constituent materials. Our extended model, which we refer to as the generalized Drude-Lorentz model, underpins all physically accessible values of both the permittivity and permeability. Using our generalized Drude-Lorentz model, we construct a generalized waveguide theory that fully respects the duality of electromagnetism.

As duality treats electric charge and magnetic monopoles on an equal footing our theory inherently includes materials with positive, negative and zero electric and magnetic susceptibilities. By exploiting the concept of magnetic monopoles our theory can easily treat arbitrary combinations of standard materials and metamaterials for select waveguide geometries.

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