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Generalized Waveguide Theory including Electromagnetic Duality

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We introduce a general theory for describing modes and characteristics
of linear, homogeneous, isotropic waveguide materials and metamaterials
with slab and cylindrical geometries.
Our theory accommodates exotic media such as double-negative-index
and near-zero-index metamaterials as special cases,
and we demonstrate that our general theory exhibits electromagnetic duality
that would arise if we were to incorporate magnetic monopoles into the media.
To ensure manifest electromagnetic duality, we construct generic electromagnetic susceptibilities for the constituent materials using a generalized Lorentz-Drude model that manifests this duality, and our model reduces to standard cases in appropriate limits.
Using our theory, we present and explain intriguing modes arising in waveguides that exploit such exotic materials and metamaterials.
In particular, we show that, in slab and cylindrical hollow-core metamaterial waveguides, exchanging electric and magnetic material properties leads to the exchange of transverse magnetic and transverse electric modes, which suggests a good test of the potential duality of waveguides.

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