Characterization of Gyromagnetic Materials Using a Partially-Filled Waveguide Technique

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The use of engineered materials in electronic systems is becoming increasingly common, and thus the need for an accurate method to characterize their electromagnetic properties is essential. These materials often have anisotropic behavior, and their permittivity or their permeability characteristics must be described using a tensor with non-zero off-diagonal entries. Few techniques are currently available for measuring these tensor constitutive parameters.

Rectangular waveguide methods are appealing for measuring anisotropic materials because of high signal strength due to field confinement, and the ability to control the polarization of the applied electric field. As a stepping stone to developing methods for characterizing materials with fully-populated tensor characteristics, techniques are being studied to characterize gyromagnetic materials for which a single parameter describes the behavior of the off-diagonal entries. Unfortunately, the available sample size for these materials is too small to completely fill the waveguide cross-section, and so standard transmission/reflection techniques, such as a modified Nicolson-Ross-Weir method, are not available.

Recently the authors have developed a method for characterizing gyromagnetic materials using a reduced-aperture waveguide in which the sample completely fills the cross-section of a narrow waveguide section. This method has several drawbacks, such as the need of a special sample holder, potential for air gaps along four walls, and reduced energy transmission due to the restriction of the narrow guide. In this paper the authors introduce a method for characterizing gyromagnetic material by placing a narrow sample into the center of a full-aperture waveguide. The drawback to this approach is the need to establish a modal description of the fields in a rectangular waveguide partially-filled with a gyromagnetic material, and to use these in a mode-matching approach for a sample section placed into a wave-guiding system. This approach is analytically more complex than the reduced-aperture method, and thus its implementation is numerically more complicated. However, the benefit of not needing a special sample holder is significant, and the potential exists for combining the two approaches to improve the values of the extracted parameters. The underlying theory will be described and the forward problem validated using synthetic data. The inverse problem will be formulated and its solution discussed.