A New Waveguide Verification Standard for the Characterization of Magnetic Materials

J. L. Frasch* and E. J. Rothwell
Department of Electrical and Computer Engineering, Michigan State University, East Lansing, Michigan, USA, 48824, rothwell@egr.msu.edu

When measuring the parameters of an unknown material for the first time, great care is needed to ensure that the responses being measured by the test system truly reflect the behavior of the material under test and not some bias or systemic error in the measurement system. One part of an appropriate procedure for testing an unknown sample involves first testing the properties of a known standard material and then comparing the results of these tests with accepted values. Unfortunately, material samples with highly predictable magnetic properties are difficult to obtain at microwave frequencies. Instead, it may be more practical to construct a surrogate test specimen with known behavior. Previously, a waveguide standard was developed consisting of a series of metallic waveguide irises that could be assembled to represent a surrogate sample region that a sample would normally occupy. When the measured S-parameters of this structure are passed through the Nicolson-Ross-Weir algorithm, a permittivity and permeability describing a material with both electric and magnetic properties are obtained. The structure was designed using a simple genetic algorithm to minimize the difference between the extracted permittivity and permeability and chosen target values.

A significant drawback of the existing waveguide standard is that it is an assembled structure, and thus does not mimic the usual procedure for measuring a sample. Thus, sources of error such as insertion position, canting, and air gaps are not replicated when measuring the standard. The purpose of the present research is to identify a set of fully insertable metallic structures that will produce predictable magnetic and electric properties when using the Nicolson-Ross-Weir algorithm. To accomplish this, a multi-criterion genetic algorithm will be used, which utilizes a multi-dimensional response surface to provide a selection of different optimal matches, varying in their quality with respect to each of the extracted parameters. For example, while one structure might provide a perfect match over the frequency band for the real part of ε, the quality of the match might suffer for the imaginary part of μ. In addition to a new optimization algorithm, a new stepped-waveguide analysis approach is being used, along with mode matching, to provide the theoretical values for comparison with the measurements. Using several of the structures in turn could provide a better validation of the system for measuring the parameters of a completely unknown magnetic material.