A Stepped Waveguide Technique for the Characterization of Conductor-Backed Absorbing Materials

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A variety of techniques have been developed for measuring the electromagnetic properties of homogeneous, isotropic materials. Commonly, a sample is excised and placed into a waveguide cross section, and the S-parameters of the system are measured. The well-known Nicolson-Ross-Weir technique is then used to find both the permeability and permittivity of the material in closed form. Certain conditions, however, prevent this approach from being used. Many radar absorbing materials are manufactured with a conductor backing that cannot be removed without potentially altering their electromagnetic properties. The materials are typically quite thin, and cannot be easily increased in thickness. Because of the conductor backing, they cannot be used to fill a waveguide cross section since no transmission would be available. Similarly, since their thickness cannot be increased, a two-thickness reflection technique cannot be employed.

A technique is proposed here in which the conductor backed material is laid on its side in a stepped waveguide. The step is a conducting extension from the bottom wall of the guide, and the material is placed between the step and the top wall of the guide. The conductor backing is placed against the step so that the material completely fills the step waveguide opening. This geometrical arrangement allows for a simple mode-matching analysis of the S-parameters of the guide. The material parameters are extracted from measurements in the usual way, by minimizing difference between the measured and theoretical S-parameter values.

Several variants of the technique are possible. If the reflection measurement proves unreliable, then multiple transmission measurements can be used with different length samples (the sample can be easily cut to size without removing the conductor backing or increasing its thickness). The sample can also be placed into different positions within the step region. A Monte Carlo error analysis can be used to determine the most effective variant. Also, an iterative mode-matching scheme for computing the S-parameters makes implementing the various schemes quite simple.

The iterative mode matching technique can also be used to explore whether multi-stepped transitions can improve the transmission through the sample. A genetic algorithm will be employed to optimize the transition based on minimizing the errors in the extracted values of permittivity and permeability due to the propagation of measurement uncertainties.