Electromagnetic Material Characterization Using a H-Plane Step Rectangular Waveguide

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Rectangular waveguides are frequently used in electromagnetic material characterization measurements due to their general availability and the relative ease in which testing samples can be machined. Measurements involving frequencies $f > 2\ GHz$ require relatively little testing material. In a S-Band waveguide ($2.5\ GHz < f < 4\ GHz$), for example, sample dimensions in the cross-sectional plane are only 2.84 inches wide by 1.34 inches in height. However, for lower-frequency applications, waveguide dimensions can be on the order of 4 feet wide by 2 feet in height. Consequently, large quantities of materials are required, leading to possible sample fabrication difficulties. Under these circumstances, a waveguide sample holder having a reduced height or width may be utilized to accommodate facilities not capable of producing such large sample sizes. This type of holder, however, will cause a disruption in the waveguide-wall currents, resulting in the excitation of higher-order modes and subsequently leading to significant errors in the computed values for the permittivity and permeability of the sample material. This paper will discuss how these higher-order modes can be accommodated in a reduced-width (i.e., H-plane) waveguide sample holder in order that the electromagnetic properties of the material may be accurately determined.

A mode-matching technique will be used to model the effects of a symmetric H-plane step sample holder. If a TE_{10} mode is incident upon the sample holder, then due to the assumed symmetry, only even TE_{m0} higher-order modes will be excited in the waveguide feed and sample holder regions. Enforcement of total tangential electric and magnetic fields at the front and back interfaces of the holder leads to a subsequent expression for the theoretical sample scattering parameters. The electromagnetic properties of the test material can then be determined numerically by comparing these theoretical values with the experimentally-measured S-parameters using a Newton's method root search, that is

$$S_{11}^{thy}(\omega,\varepsilon,\mu) - S_{11}^{exp}(\omega) = 0$$
$$S_{21}^{thy}(\omega,\varepsilon,\mu) - S_{21}^{exp}(\omega) = 0$$

Experimental results for several sample materials will be provided and compared with the ideal case. Experimental plots of permittivity and permeability will be given showing the effects that the number of modal expansion terms have on convergence.

† The views of the co-author expressed in this article do not reflect the official policy of the U.S. Air Force, Department of Defense, or the U.S. Government.