**Microwave Material Characterization Using the Resonant Clamped Circular Waveguide Technique**

**Trent Moritz, Matthew Dvorsky, and Mohammad Tayeb Al Qaseer**

Center for Nondestructive Evaluation (CNDE)

Iowa State University, Ames, IA

tdmoritz@iastate.edu

ABSTRACT

This work presents a method for performing microwave material characterization using the clamped circular waveguide technique, operating in a resonant configuration. The clamped waveguide technique is a nondestructive development of the destructive filled waveguide technique, which is considered a relatively accurate material characterization technique for most materials. However, both the clamped and filled waveguide techniques struggle with accurately characterizing thin and low loss materials, due to lack of sensitivity. Generally, resonant cavity techniques are used to obtain more accurate results for these types of materials. However, cavity techniques are also destructive, requiring the material under test (MUT) to be cut and shaped. Using the clamped circular waveguide technique, resonant conditions can be generated by clamping additional (known) materials on either side of the MUT. The materials that are clamped on either side of the MUT must have well-known material properties (permittivity, permeability, and thickness) and must be low loss. When the resonant conditions are met, the measurement becomes very sensitive to any perturbations in the permittivity, permeability, or thickness of the MUT. As a result, when even a very thin MUT is placed between the clamping materials, the resonant frequency and Q-factor of the resonance will be highly sensitive to the properties of the MUT, allowing complex permittivity (or other properties) to be determined with a high degree of accuracy.

The proposed technique was validated through full-wave electromagnetic simulations that were performed of a clamped circular waveguide operating at 10.2-12 GHz. To create a resonance, two 2 mm pieces of quartz (=4.00-j0.0004) were placed on either side of the MUT. Simulations and measurements were performed for a thin (1 mm-thick) piece of acrylonitrile butadiene styrene (ABS) with reported permittivity of =2.5-j0.055. To illustrate the sensitivity to the MUT complex permittivity when operating in this resonant mode, simulations are shown in which the real part of the permittivity was varied from 2 to 3 and the imaginary part was varied from 0.01 to 0.1. Fig. 1 shows the results of the simulations and the impact of varying the complex permittivity on the resonance. The results indicate that this method is very sensitive near the resonance as indicated by the shift in resonant frequency and depth of the resonance. The increase in sensitivity is highlighted by comparing the resonant region (11.5-11.8 GHz) to the non-resonant region (10.2-11.2 GHz). The presentation will describe the methodology of this method, its applications, and its accuracy in measuring complex permittivity of thin low loss materials.



Figure 1: Impact of complex permittivity on resonant response.

Acknowledgements

This work has been supported by the center for nondestructive evaluation (CNDE) GRA and Trapp fellowship.