Measurement of Dielectric Properties of Thin Materials for Radomes with Simple Waveguide Cavities

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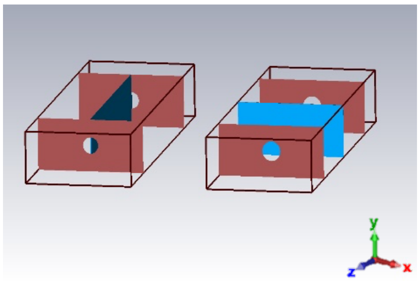
The characteristics of dielectric materials play a significant role when being used within the radio frequency spectrum. When deciding on materials for radomes, it is especially important to know how much a material may interfere with the device it is protecting. Waveguide cavity resonators are a widely used method of determining permittivity and loss tangent, especially for thin and low loss materials. Here we use a waveguide cavity that requires only a length of waveguide, two readily manufactured irises, and a scalar or vector network analyser. The method is structured around the standard TM and TE propagation modes of the EM field and operates by observing the frequency and Q factor changes in a resonant cavity upon introducing the dielectric. The measurement test setup is depicted in Fig. 1(a). The characteristics of a material can be calculated using the following Equation [1, 2].

$$\epsilon_r = \left(\frac{f_o - f_s}{2f_s}\right)\left(\frac{V_c}{V_s}\right) + 1 \quad , \; \epsilon_{im} = \left(\frac{V_c}{4V_s}\right)\left(\left(\frac{1}{Q_s}\right) - \left(\frac{1}{Q_o}\right)\right) \tag{1}$$

The resonant frequencies (f_o and f_s) and quality factors (Q_o and Q_s) represent the behaviour before and after the cavity is filled with the test material. V_s and V_c are volumes of the test material and the cavity. A study of the field structure reveals the orientation of the material within the cavity is also important, as the cavity modes will 'see' different amounts of the material dependent upon their orientation. As such, we used the orientation of the y-z plane, as opposed to the x-y plane (Fig. 1(a)).



		Material Samples								
Simulated Results	εr	1.5			2.2			2.9		
	tanδ	0.1	0.05	0.001	0.1	0.05	0.001	0.1	0.05	0.001
Calculated Results	εr	1.4805	1.4979	1.5006	2.1893	2.2029	2.2052	2.9354	2.9395	2.9151
	tanδ	0.104	0.051	0.001	0.104	0.053	0.001	0.101	0.05	0.001
Error (%)	εr	1.30	0.14	0.04	0.49	0.13	0.24	1.22	1.36	0.52
	tanδ	4.00	2.00	0.00	4.00	6.00	0.00	1.00	0.00	0.00

(a) (b)

Fig. 1: (a) Different orientations of test material in cavity (y-z plane, left side, x-y plane, right side), (b) Simulated and calculated permittivity and loss tangent of the WR650 cavity and shim with diameter of 12.2mm.

We initially ran simulations within CST Studio Suite [3] across various permittivity and loss tangents to determine multiple reliable shim diameters for different modes for WR650 and WR137 waveguide cavities. Fig. 1(b) compares the results calculated from Equation (1) with the materials that have been used in the CST simulation for showing the accuracy of the method. Accurate results with error of less than 1.5% for permittivity and 6% for loss tangent have been calculated for our chosen shim sizes for WR137 and WR650 waveguide cavities. The next step will be to manufacture the shims, place the radome material samples in each waveguide cavity (supported by foam blocks) and measure resonant frequency and Q-factor on a network analyser to determine the permittivity and loss tangent for each material.

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[3] Studio, CST Microwave. "CST Microwave studio." CST Studio Suite (2023).