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MEASUREMENT OF THE COMPLEX DIELECTRIC CONSTANT OF LOW-LOSS CASTING RESINS AT MILLIMETER WAVELENGTHS

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ABSTRACT

A quasi-optical method for measuring the complex dielectric constant of materials is described. The determination is derived from measurements of the transmission of a perpendicularly polarized wave through a dielectric slab at different angles of incidence. The complex permittivities of various low-loss casting resins have been measured using this method.

At the short millimeter and sub-millimeter wavelengths the use of quasi-optical components in low-noise radiometric, communication and radar systems is mandatory since conventional waveguides are too lossy in this region of the electromagnetic spectrum. Integral parts of these quasi-optical components are low-loss lenses, and the proper design of these devices require accurate measurements of the complex dielectric constant of the lens material at the operational frequency. Waveguide methods are not suited for accurately determining the relative dielectric constant and the loss tangent of materials at millimeter wavelengths and shorter.

In the quasi-optical method described in this paper the complex dielectric constant is determined from measurement of the transmission of a perpendicularly polarized wave through the sample dielectric etalon at different angles of incidence. A schematic of the experiment is shown in Figure 1. The reflection coefficient of a perpendicuarly polarized wave at a dielectric boundary is equal to or greater than that of a parallel polarized wave at any angle of incidence. In a Fabry-Perot etalon, the contrast, defined here as the ratio of an adjacent transmission maximum (angular position) and minimum, increases with reflectivity. The use of a perpendicularly polarized wave gives a more accurate measure of the angular position of the transmission peaks and valleys, and in turn, a better estimate of the real part of the dielectric constant. The loss tangent is primarily determined by the amplitude level. The relative dielectric constants (ε_r) and loss tangents (tan δ) of various low loss dielectrics at 93.8 GHz were determined using this method. Figure 2 shows the measured power transmissions of a perpendicularly polarized wave through a slab of 36D, a casting resin, at various incident angles. The solid line is the theoretical curve using the best fit estimate of ε_r and tan δ for that material. The dots are the measured points.

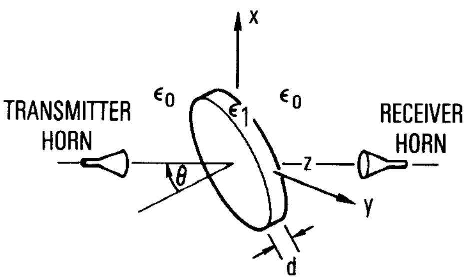

Fig. 1 The illustration shows a quasi-optical method for determining the complex dielectric constant of materials at the millimeter and sub-millimeter wavelengths in which the determination is made by measuring the power transmission of a perpendicularly polarized wave through the sample dielectric etalon at various angles of incidence.

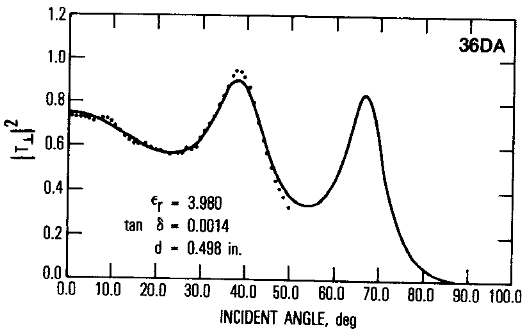

Fig. 2 The measured values of the power transmission of a perpendicularly polarized wave through an 0.498 inch thick 36DA resin etalon at a frequency of 93.788 GHz are shown in the illustration. The solid line is the theoretical curve using the best fit values of the relative dielectric constant, ε_r, and loss tangent, tan δ.

The accuracy of this method for determining the complex permittivity of dielectrics and the comparison with other methods have been more completely described in a previous study (1). In this paper, the method has been further applied to determine the complex permittivities of materials which have been fabricated by the mixture of a base resin and low-loss microspheres.

The reasons for investigating the dielectric properties of these resin materials for use at the millimeter and sub-millimeter wavelengths are twofold. First these resins are castable, and this is an advantage when a number of identical dielectric component shapes are needed. Second, these resins have a determinable dielectric constant, such that they can be used in conjunction with other dielectrics to fabricate non-reflective surfaces.

A line of low-loss casting resins for use at microwaves are commercially available along with a dielectric material composed of micro-sized thin-walled silica bubbles (Emerson & Cuming, Inc.). These microspheres have an average particle diameter of 80 microns, and have an advertised effective dielectric constant of 1.2 and a loss tangent of .0005. When mixed with a base resin, dielectrics with various dielectric constants can be synthesized. The measured complex permittivities of various casting resins are shown in Table 1. The permittivities of the materials 36DS, 36D, 36DA, and 36 DK have been determined previously. The number in parenthesis is the fraction by volume, of the base resin 36D in the material. For example, the material 36D(.5) is composed of 50% 36D, and 50% silica microspheres, by volume.

TABLE 1
ESTIMATES OF THE COMPLEX PERMITTIVITIES OF CASTING RESINS

f = 93.788 GHz

Material	Relative Permittivity, ε_r	Loss Tangent, $\tan \delta$
36DS	1.765	.004
36D	2.485	.001
36DA	3.98	.001
36DK	5.69	.004
36D(.5)	1.94	.002
36D(.55)	1.98	.002
36D(.6)	2.06	.002
36D(.7)	2.14	.002
36D(.8)	2.34	.002

It is seen that 36D(.55) and 36D(.8) are good anti-reflective coatings for 36DA and 36DK, respectively.

References

(1) F.I.Shimabukuro, S.Lazar, M.R.Chernick, and H.B.Dyson, "A Quasi-Optical Method for Measuring the Complex Permittivity of Materials," to be published in the IEEE Transactions on Microwave Theory and Techniques.