Designation: D 5568 – 01

An American National Standard

# Standard Test Method for Measuring Relative Complex Permittivity and Relative Magnetic Permeability of Solid Materials at Microwave Frequencies[1]

This standard is issued under the fixed designation D 5568; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method covers a procedure for determining relative complex permittivity (relative dielectric constant and loss index) and relative magnetic permeability of isotropic, reciprocal (nongyromagnetic) solid materials. If the material is nonmagnetic, this procedure may be used to measure permittivity only.

1.2 This measurement method is valid over a frequency range of approximately 1 MHz to 50 GHz. These limits are not exact and depend on the size of the specimen, the size and type of transmission line used as a specimen holder, and on the applicable frequency range of the network analyzer used to make measurements. The lower frequency is limited by the smallest measurable phase shift through a specimen, and the upper frequency limit is determined by the excitation of higher-order modes that invalidates the dominant-mode transmission line model. Any number of discrete measurement frequencies may be selected in this frequency range. To achieve maximum measurement accuracy, use of different transmission line sizes and types may be required. For example, use of a 7-mm diameter coaxial geometry can provide for measurements from 1 MHz to 18 GHz. However, air gaps that exist between the specimen and the transmission line's conductors introduce errors[2] that may necessitate the use of a larger diameter coaxial transmission line and a series of rectangular wave guides of different size to cover this frequency range.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

2.1 *ASTM Standards:*

D 1711 Terminology Relating to Electrical Insulation[3]

## 3. Terminology

3.1 For other definitions used in this test method, refer to Terminology D 1711.

3.2 *Definitions:*

3.2.1 *relative complex permittivity (relative complex dielectric constant) (relative complex capacitivity),* $\epsilon_R$, *n*—the ratio of the admittance of a given configuration of the material to the admittance of the same configuration with vacuum as dielectric:

$$\epsilon^*_R = \frac{Y}{Y_\upsilon} = \frac{Y}{j\omega C\upsilon} = \epsilon'_R - j\epsilon''_R, \tag{1}$$

where $Y$ is the admittance with the material and $j\omega C'\upsilon$ is the admittance with vacuum.

3.2.1.1 *Discussion*—In common usage the word "relative" is frequently dropped. The real part of complex relative permittivity ($\epsilon'_R$) is often referred to as simply relative permittivity, permittivity or dielectric constant. The imaginary part of complex relative permittivity ($\epsilon''_R$) is often referred to as the loss index. In anisotropic media, permittivity is described by a three dimensional tensor.

3.2.2 For the purposes of this test method, the media is considered to be isotropic, and therefore permittivity is a single complex number.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 A list of symbols specific to this test method is given in Annex A1.

3.3.2 *calibration, n*—a procedure for connecting characterized standard devices to the test ports of a network analyzer to characterize the measurement system's systematic errors. The effects of the systematic errors are then mathematically removed from the indicated measurements. The calibration also establishes the mathematical reference plane for the measurement test ports.

3.3.2.1 *Discussion*—Modern network analyzers have this capability built in. There are a variety of calibration kits that

[1] This test method is under the jurisdiction of ASTM Committee D09 on Electrical and Electronic Insulating Materials and is the direct responsibility of Subcommittee D09.12 on Electrical Tests.

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[2] ASTM STP 926 "Engineering Dielectrics, Volume 11B, Electrical Properties of Solid Insulating Materials: Measurement Techniques," 1987.

[3] *Annual Book of ASTM Standards,* Vol 10.01.

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