Designation: A893/A893M – 03(Reapproved 2008)

Standard Test Method for Complex Dielectric Constant of Nonmetallic Magnetic Materials at Microwave Frequencies[1]

This standard is issued under the fixed designation A893/A893M; 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 the measurement of the complex dielectric constant of isotropic ferrites for extremely high-frequency applications.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. Within this standard, SI units are shown in brackets.

1.3 *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. Summary of Test Method

2.1 In an isotropic dielectric medium with a steady electric field, E, the electric displacement, D, is given by the equation:

$$D = k\varepsilon_0 E \quad (1)$$

where:

ε_0 = permittivity of free space and
k = dielectric constant. If the medium is subjected to an alternating electric field, the electric displacement is not necessarily in phase with the field. This fact may be expressed mathematically by taking k as a complex quantity. If we write $k = k' - jk''$, the imaginary part, k'', determines the dissipation in the medium.

2.2 This test method uses a cavity perturbation technique as a means of separating electric from magnetic effects. Quantities that must be measured are the resonance frequency, f, of the cavity with and without the sample, the loaded Q of the cavity with and without the specimen, and the cavity and specimen dimensions.

2.3 The specimen is in the form of a rod and is placed parallel to the microwave electric field in a region of substantially uniform electric and zero microwave magnetic fields. The perturbation theory requires that the diameter of the sample rod be small compared to one quarter of the wavelength of the microwave radiation in the specimen. Estimation of this wavelength requires knowledge of the permittivity, $\varepsilon = k\varepsilon_0$, and permeability, μ, of the specimen under the conditions of measurement. The wavelength, λ, in the specimen is given by the equation:

$$\lambda = 1/f'(\mu\varepsilon)^{1/2} \quad (2)$$

For many ferrites, μ may be taken equal to μ_0, the permeability of empty space, without serious error. The permittivity, ε, is determined by measurement as described below; after obtaining a value of ε, it is necessary to ascertain with the aid of Eq 1 that the sample diameter is sufficiently small.

2.4 This test method is not suitable for materials with loss tangents ≥0.1, with the loss tangent defined as $\tan\delta = k''/k'$.

2.5 The results of the perturbation theory calculation may be expressed in the form:

$$\delta f/f = [-(k-1)\,|Miv_s E^o E^i dv]/2|Miv_c (E^o)^2\, dv \quad (3)$$

where:

f = $f' + jf''/2Q$;
Q = loaded Q of the cavity;
v_s = specimen volume contained within the cavity, in.^{3} [mm^3];
v_c = cavity volume, in.^{3} [mm^3]; and
E = microwave electric field strength.

The superscript o refers to fields in the empty cavity and the superscript i refers to fields inside the specimen.

2.6 A specific cavity suitable for this test method is a TE_{10n} rectangular cavity,[2] where n is odd. With the rod running

[1] This test method is under the jurisdiction of ASTM Committee A06 on Magnetic Properties and is the direct responsibility of Subcommittee A06.01 on Test Methods.

Current edition approved May 1, 2008. Published June 2008. Originally approved in 1963. Last previous edition approved in 2003 as A893/A893M–03. DOI: 10.1520/A0893_A0893M-03R08.

[2] See, for example, Montgomery, C. G., Ed., *Technique of Microwave Measurements*, McGraw-Hill Book Co., Inc., New York, 1947, pp. 294–295; Bronwell and Beam , *Theory and Application of Microwaves*, McGraw-Hill Book Co., Inc., 1947, pp. 368–337.