



Standard Test Method for Ferrimagnetic Resonance Linewidth and Gyromagnetic Ratio of Nonmetallic Magnetic Materials¹

This standard is issued under the fixed designation A 883/A 883M; 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 ferrimagnetic resonance linewidth and gyromagnetic ratio of isotropic microwave ferrites. This test is restricted to spherical specimens possessing resonance linewidths greater than 10 Oe [796 A/m].

1.2 The values and equations stated in customary (cgs-emu and inch-pound) or SI units are to be regarded separately as standard. Within this standard, SI units are shown in brackets. 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 nonconformance with this standard.

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 Methods

2.1 Ferrite materials, in general, exhibit at microwave frequencies a power loss or absorption which is a function of an applied DC magnetic field. In many ferrites, this dependence is of a simple form, having a single maximum at some value of the magnetic field, which depends on the microwave frequency and on the specimen shape. For ferrite materials showing this behavior, it is useful to characterize the absorption by means of an effective gyromagnetic ratio and a resonance linewidth. Note that ferrite materials exist for which the absorption has a more complex behavior as a function of DC magnetic field; this method is not intended to apply to such materials.

2.2 The value of the field for maximum absorption or resonance may be computed in terms of the magnetization of the sample, its geometry, the *effective gyromagnetic ratio*, γ , and the test frequency. For the case of a small spherical

specimen, the dependence on specimen magnetization drops out and the effective gyromagnetic ratio can be computed from the relationship:

$$\omega = \gamma H_r \quad (1)$$

where:

$$\omega = 2\pi f;$$

f = microwave frequency, MHz; and

H_r = resonance magnetic field strength, Oe [A/m].

2.3 The second quantity characteristic of the absorption is the *ferrimagnetic resonance linewidth*, ΔH , which for the method described shall be defined as the separation of the two magnetic field values at which the power absorbed by the ferrite material is one half the maximum absorption. The performance obtainable in specific devices such as isolators, rotators, and so forth, is related to the linewidth and gyromagnetic ratio.

2.4 This test method of measuring the ferrimagnetic resonance linewidth and the gyromagnetic ratio of a ferrite material uses a cavity perturbation technique, which requires that the specimen be small compared to one quarter of the wavelength of the microwave radiation in the sample. Estimation of this wavelength requires knowledge of the relative dielectric constant, k , and permeability, k_m , of the specimen material under the conditions of measurement. The relative permeability depends on both the frequency and the magnetic field, but can be taken as -2 for the resonance condition in a sphere. The wavelength in centimetres, λ , in the specimen is then approximated by the equation:

$$\lambda = 3 \times 10^4 / \sqrt{k} \quad (2)$$

2.5 The absorption in the specimen is measured by determining the changes of power incident on the cavity required to keep the output power from the cavity at a fixed reference level. It is necessary that the microwave frequency be adjusted to cavity resonance for all measurements. The variations in input power may be characterized by the variations of the attenuation inserted between a monitored source and the cavity to maintain the reference output level. If α_0 is this attenuator reading in decibels with no sample present, and α_r is this reading for maximum specimen absorption, then the reading

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 Oct. 10, 2001. Published December 2001. Originally published as C 524 – 63 T. ASTM Test Method F 130 – 86 was redesignated as A 883 – 86e¹ in 1989. Last previous edition A 883 – 96.

corresponding to a specimen absorption of half the resonance value is given by the equation:

$$\alpha_{1/2} = \alpha_0 + 20 \log 2 - 20 \log (10^{(\alpha_0 - \alpha_r/20)} + 1) \quad (3)$$

3. Significance and Use

3.1 This test method can be used to evaluate materials such as garnets and so forth for intrinsic loss factors that can be used in the design of microwave devices such as absorbers, circulators, rotators, and so forth.

3.2 This type of data is constantly reported in the literature and research papers on these types of materials as a quality and design factor for the applications at microwave frequencies.

4. Apparatus

4.1 Fig. 1 is a schematic diagram of the equipment required to make these measurements. Power from a suitable microwave source, A, operated either unmodulated or with amplitude modulation, but free of frequency modulation, is fed through a precision variable attenuator, F, to the cavity, G, and the output power is detected and indicated on a suitable meter, H. The power incident on the precision attenuator is monitored at E by means of a directional coupler, D, and crystal detector, and this incident power is kept constant throughout the measurement by means of a variable attenuator, C. The microwave frequency is variable and must be adjusted to cavity resonance for all measurements, as indicated by maximum power output with respect to frequency variation. An adjustable magnetic field is applied across the specimen region perpendicular to the microwave magnetic field. The inhomogeneity of the applied field over the specimen region must be small compared to the linewidth being measured.

5. Test Specimen and Cavity

5.1 The specimen is in the form of a small polycrystalline sphere. The maximum diameter of the specimen is restricted by both 2.4 and 2.5. At 9000 to 10 000 MHz, a diameter of 0.040 in. [1.02 mm] will fulfill the requirements for most specimens. A typical cavity is of the transmission type, resonant between

9000 and 10 000 MHz, with a loaded Q (Q_0) greater than 2000. The specimen is positioned away from the cavity walls at a point of minimum microwave electric field and maximum microwave magnetic field. In Fig. 2 a suitable cavity is shown and the proper specimen position is indicated. The specimen is mounted on a fused silica or other dielectric rod. The hole for inserting the specimen into the cavity is located in the narrow cavity wall and is no larger than 0.075 in. [1.90 mm] in diameter for the X-band cavity. The input and output lines to the cavity are made to appear as matched loads by means of pads or isolators.

6. Procedure

6.1 Establish, with no specimen present, an input level measured at E, a setting, α_0 , on the precision attenuator, and an output level measured at H. Take this output level as a reference for the remaining measurements. Insert the specimen into the cavity and vary the external magnetic field until the point of maximum specimen absorption is found, as indicated by minimum transmission. Determine the microwave frequency, f , and magnetic field, H_r , at this point by suitable means. Thus, f may be measured with a wave meter at B, and H_r by a rotating coil fluxmeter, Hall effect probe, nuclear magnetic resonance probe, and so forth. The gyromagnetic ratio may be computed by means of Eq 1.

6.2 Determine the attenuation, α_r , required to obtain the reference output level at resonance. Compute the attenuation, $\alpha_{1/2}$, required to obtain the reference output level at the half-power points of specimen absorption from Eq 3. Insert this amount of attenuation with the precision attenuator, and determine the magnetic field at the two points at which the output reaches the reference value. The difference in the magnetic fields at these two points is the ferrimagnetic resonance linewidth, ΔH .

6.3 The value of ΔH and H_r obtained from these measurements shall satisfy the equation:

$$\alpha_0 - \alpha_r [La 20 \log [1 + (0.06Q_0\Delta H/H_r)]] \quad (4)$$

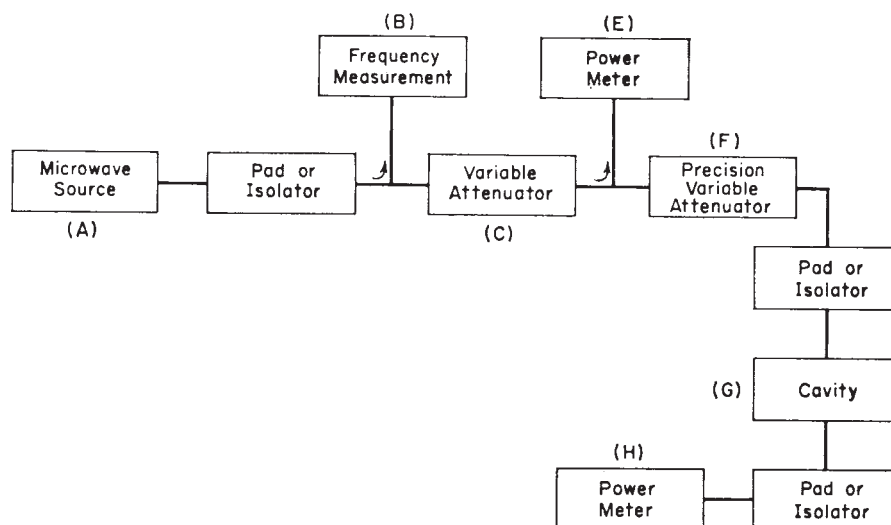
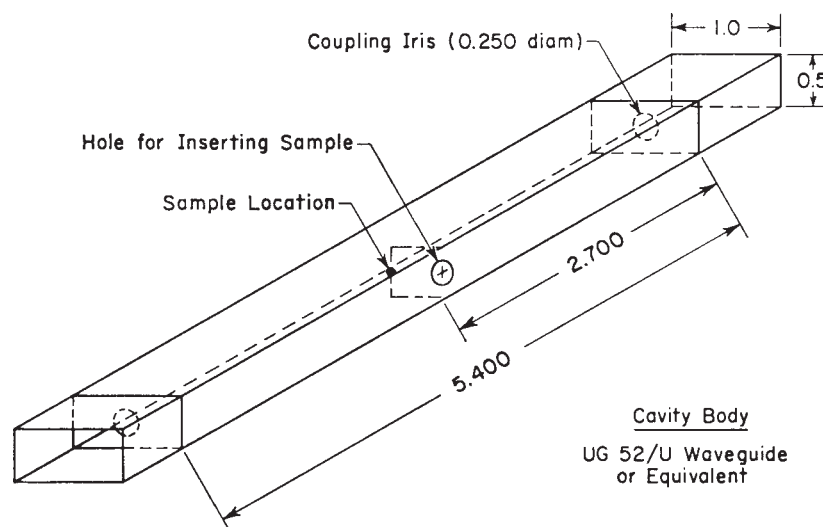


FIG. 1 Schematic Diagram of Equipment Required for Measurement of Ferrimagnetic Resonance Linewidth and Gyromagnetic Ratio



NOTE 1—All dimensions are given in inches, the conversion factor for SI units is 1 in. = 25.4 mm.

FIG. 2 Typical Cavity for Measurement of Ferrimagnetic Resonance Linewidth and Gyromagnetic Ratios at 9300 MHz

If the equation is not satisfied by the data, then the sphere diameter must be reduced until the loss difference meets the above requirement.

6.4 To check the sphericity and isotropy, the specimen should be rotated in the cavity and the resonance field value, H_r , and the ferrimagnetic resonance linewidth, ΔH , observed as a function of specimen rotation. The value obtained for H_r and ΔH should not depend on specimen orientation. Allowable limits shall be 1 % variation in H_r and 5 % variation in ΔH .

7. Report

7.1 Report values of gyromagnetic ratio, γ , ferrimagnetic resonance linewidth, ΔH , and the frequency and temperature at which the measurements were made. The gyromagnetic ratio

may be given in units other than those implied by Eq 1; in any case, the appropriate units shall be explicitly stated. The unique identity of the specimen shall also be included in the report.

8. Precision and Bias

8.1 Frequencies shall be measured with a bias of $\pm 1\%$ magnetic field with a bias of $\pm 2\%$, and the field difference between the half-power points of specimen absorption with a bias of $\pm 5\%$.

9. Keywords

9.1 ferrimagnetic; ferrimagnetic resonance linewidth; ferrite; fmr linewidth; gyromagnetic ratio; linewidth

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