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NORME INTERNATIONALE

colour inside

Gyromagnetic materials intended for application at microwave frequencies – Measuring methods for properties

Matériaux gyromagnétiques destinés à des applications hyperfréquences – Méthodes de mesure des propriétés

IEC 60556:2006-04+AMD1:2016-03 CSV(en-fr)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

GYROMAGNETIC MATERIALS INTENDED FOR APPLICATION AT MICROWAVE FREQUENCIES – MEASURING METHODS FOR PROPERTIES

FOREWORD

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IEC 60556 edition 2.1 contains the second edition (2006-04) [documents 51/850/FDIS and 51/859/RVD] and its amendment 1 (2016-03) [documents 51/1064/CDV and 51/1089A/RVC].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

International Standard IEC 60556 has been prepared by IEC technical committee 51: Magnetic components and ferrite materials.

This second edition is a consolidation of the first edition and its amendments 1 and 2. It includes editorial improvements as well as improvements to the figures.

This standard is to be read in conjunction with IEC 60392.

The French version of this standard has not been voted upon.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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GYROMAGNETIC MATERIALS INTENDED FOR APPLICATION AT MICROWAVE FREQUENCIES – MEASURING METHODS FOR PROPERTIES

1 Scope

This International Standard describes methods of measuring the properties used to specify polycrystalline microwave ferrites in accordance with IEC 60392 and for general use in ferrite technology. These measuring methods are intended for the investigation of materials, generally referred to as ferrites, for application at microwave frequencies.

Single crystals and thin films generally fall outside the scope of this standard.

NOTE 1 For the purposes of this standard, the words “ferrite” and “microwave” are used in a broad sense:

– by “ferrites” is meant not only magneto-dielectric chemical components having a spinel crystal structure, but also materials with garnet and hexagonal structures;

– the “microwave” region is taken to include wavelengths approximately between 1 m and 1 mm, the main interest being concentrated on the region 0,3 m to 10 mm.

NOTE 2 Examples of components employing microwave ferrites are non-reciprocal devices such as circulators, isolators and non-reciprocal phase-shifters. These constitute the major field of application, but the materials may be used in reciprocal devices as well, for example, modulators and (reciprocal) phase-shifters. Other applications include gyromagnetic filters, limiters and more sophisticated devices, such as parametric amplifiers.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendment) applies.

IEC 60050-221, *International Electrotechnical Vocabulary (IEV) – Part 221: Magnetic materials components*

IEC 60205:2006, *Calculation of the effective parameters of magnetic piece parts*

IEC 60392:1972, *Guide for the drafting of specifications for microwave ferrites*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-221 apply.

4 Saturation magnetization M_s

4.1 General

Saturation magnetization is a characteristic parameter of ferrite materials. It is widely used in theoretical calculations, for instance in computation of tensor permeability components (see IEC 60050-221). In a variety of microwave applications, saturation magnetization determines the lower frequency limit of the device, mainly due to the occurrence of so-called low-field loss when the material is unsaturated.

4.2 Object

The object is to give two similar techniques for measuring saturation magnetization. These are the vibrating coil method (VCM) and vibrating sample method (VSM).

The vibrating coil method [1][1] [2] has the advantages of easier sample mounting and simpler mechanical arrangement when measurements over a range of temperatures are required, particularly at low temperatures.

The vibrating sample method is more accurate, given a similar degree of elaboration in electronic apparatus.

The equipment needed in both cases is very similar and the calibration methods are identical. The same test samples can be used for either technique.

4.3 Theory

When a sphere of isotropic magnetic material is placed in a uniform magnetic field, the sphere becomes uniformly magnetized in the direction parallel to the applied field. The sphere now produces its own external magnetic field, equivalent to that of a magnetic dipole at the centre of the sphere and orientated parallel to the direction of magnetization.

If a small detection coil (in practice a pair wound in opposition) is now vibrated at small amplitude, close to the sample sphere and in a direction at right angles to the applied field, a voltage e_s, will be induced in the coil, proportional to the rate of change of flux φ_s due to the sample at the mean coil position x_0 whose value is given by

$$e_s = -N \cdot \left(\frac{d\varphi_s}{dx} \right)_{x_0} \cdot \frac{dx}{dt} \tag{1}$$

where N is the number of turns on the coil.

The motion of the coil, in the x-direction, is given by

$$x = x_0 + \delta \sin \omega t \tag{2}$$

where

x is displacement at time t;

ω is angular frequency;

δ is vibration amplitude.

If the unknown sample is now replaced by a calibrating sample of known saturation magnetization M_c and volume V_c, inducing a voltage e_c, the magnetization of the sample M_s may be found by comparison:

$$\frac{M_s}{M_c} = \frac{e_s}{e_c} \cdot \frac{V_c}{V_s} \tag{3}$$

If the induced voltages e_s and e_c give rise to readings E_s and E_c from the apparatus, then

$$M_s = M_c \cdot \frac{E_s}{E_c} \cdot \frac{d_c^3}{d_s^3} \tag{4}$$

where d_s and d_c are diameters of the sample and calibrating spheres, respectively.

[1] Figures in square brackets refer to the bibliography.

Identical equations apply in the VSM case, when the sample is vibrated while the coil remains stationary.

4.4 Test sample

For the dipole assumption to be valid, the test sample shall be a sphere, whose deviation from roundness is not more than 0,5 %. The percentage deviation from roundness is defined as

$$\left(\frac{\text{max. diameter} - \text{min. diameter}}{\text{min. diameter}}\right) \times 100 \qquad (5)$$

For most ferrite materials, a diameter of about 2,5 mm is suitable. If it is less than 1 mm, a reasonable signal-to-noise ratio will be difficult to achieve, particularly when M_s is low. Spheres larger than about 4 mm are less convenient to make and it is not so easy to maintain a uniform applied field over the volume of the sphere.

It may be permissible to use other than spherical samples, provided that the induced voltage can be shown to be a linear function of the magnetization to within the accuracy required, and that the calibration sample has identical dimensions to the samples to be measured.

4.5 Measuring apparatus for the vibrating coil method (VCM)

4.5.1 Arrangement of detection coils and sample

A schematic diagram of the arrangement of the detection coils and the sample is shown in Figure 1. Figure 2 indicates the directions of the applied and sample fields.

The sample is rigidly mounted between the pole-pieces of an electromagnet, in such a way that its position relative to the detection coils is reproducible to ±0,1 mm in any direction. All parts of the sample holder shall be made of non-magnetic material.

The detection coils are an identical pair wound in series opposition. They are attached to the vibrator by a rigid, non-magnetic arm and are located as close to the sample as practicable. Their axes are normally parallel to the direction of vibration, but other configurations are acceptable.

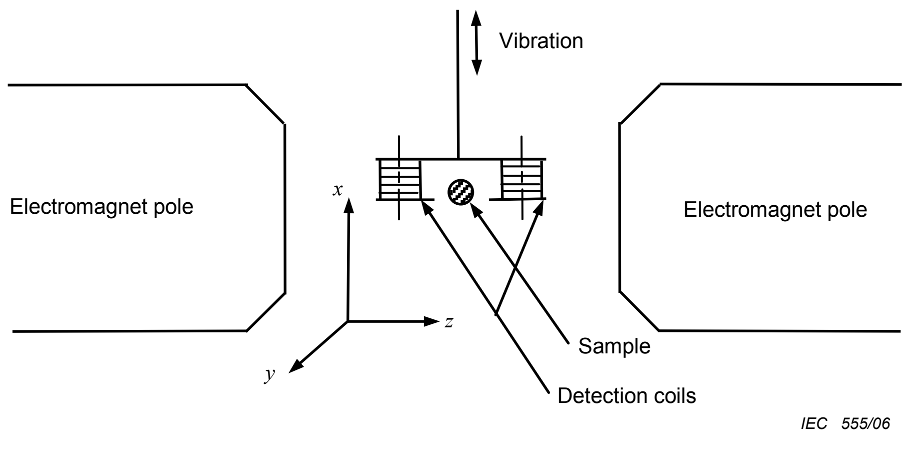

Figure 1 – Vibrating coil method – Sample and coils arrangement