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TECHNICAL REPORT

Measurement methods of the complex relative permeability and permittivity of noise suppression sheet

colour inside

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MEASUREMENT METHODS OF THE COMPLEX RELATIVE PERMEABILITY AND PERMITTIVITY OF NOISE SUPPRESSION SHEET

FOREWORD

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IEC TR 63307, which is a technical report, has been prepared by IEC technical committee 51: Magnetic components, ferrite and magnetic powder materials.

The text of this Technical Specification is based on the following documents:

Draft TR	Report on voting
51/1349/DTR	51/1356/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,
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INTRODUCTION

Noise suppression sheet (NSS) is used near the source of high frequency electromagnetic noise, path of noise propagation and source of emission. It is used like a patch and is different from an electromagnetic wave absorber in free space. IEC 62333-2 specifies five measurement methods in order to estimate the effect of NSS. To evaluate the effect by computer simulation, it is indispensable to know the frequency characteristics of both permeability and permittivity. And to make a rough estimate of the noise suppression effect of NSS, it is useful to understand effective permeability and effective permittivity, which are the permeability and permittivity of an actually used shape.

As most NSSs are flexible, and both complex relative permeability and complex relative permittivity have anisotropy, careful study and understanding of the principles are indispensable for the measurement of the frequency characteristics of permeability and permittivity.

There are various methods to measure permeability and permittivity under the frequency range where NSS is used. This document is intended to be used for the proper selection of the measurement method and the preparation of the test sample to achieve the above purpose when measuring permeability and permittivity, the two parameters which largely influence the noise suppression effect of the NSS.

MEASUREMENT METHODS OF THE COMPLEX RELATIVE PERMEABILITY AND PERMITTIVITY OF NOISE SUPPRESSION SHEET

1 Scope

This document provides guidelines on the methods for measuring the frequency characteristics of permeability and permittivity in the frequency range of 1 MHz to 6 GHz for a noise suppression sheet for each electromagnetic noise countermeasure.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
noise suppression
suppression which consists of signal decoupling, radiation suppression and attenuation of the transmission power of noise by an electronic product

Note 1 to entry: Each function above is achieved by absorption and/or shielding.

3.1.2
noise suppression sheet
NSS
sheet which enables noise suppression and is composed of magnetic, dielectric or conductive material with electromagnetic losses

EXAMPLE Sheet made of soft magnetic metal powder and resin or rubber.

3.1.3
suppression ratio
ratio of the noise level with and without suppression sheets

Note 1 to entry: The suppression ratio is classified into intra-decoupling ratio, inter-decoupling ratio, transmission attenuation power ratio and radiation suppression ratio. It is expressed in dB.

3.2 Symbols

μ_r	complex relative permeability
μ_r'	real part of complex relative permeability
μ_r''	imaginary part of complex relative permeability
ε_r	complex relative permittivity

ε'_r real part of complex relative permittivity

ε''_r imaginary part of complex relative permittivity

Z impedance (Ω)

$\omega = 2\pi f$ angular frequency (rad/s)

I current (A)

$B = \mu_0\mu_r H$ magnetic flux density (T)

H magnetic field strength (A/m)

μ_0 permeability of vacuum ($4\pi \times 10^{-7}$ H/m)

f frequency

4 General

Composite materials made by embedding magnetic metal flakes in a plastic sheet are widely used in PCs or mobile phone handsets. This sheet is well known as a noise suppression sheet (NSS) and is used to reduce unwanted signals in transmission lines or unwanted couplings between circuit elements in the devices described above.

Electromagnetic compatibility (EMC) designers recently have been using simulations for the design of the circuit boards for PCs and mobile phone handsets. In these simulations, it is important to know the complex relative permeability μ_r and the complex relative permittivity ε_r of NSS. This document shows the six measurement methods of μ_r and ε_r of NSS. The measurement frequency range is from 1 MHz to 6 GHz, as shown in Table 1. Figure 1 illustrates the in-plane and perpendicular measurement direction of Table 1.

Table 1 – Measurement method and frequency

Method Name	μ_r and ε_r				Frequency
	In-plane		Perpendicular		1 MHz to 10 MHz / 100 MHz / 1 GHz / 10 GHz / 100 GHz
	μ_r	ε_r	μ_r	ε_r	
5.1 Inductance	○				1 MHz to 1 GHz
5.2 Nicolson Ross Weir	○	○			500 MHz to
5.3 Short-circuited micro strip line	○				10 MHz to 10 GHz
5.4 Short-circuited coaxial line	○	○			1 MHz to 18 GHz
5.5 Shielded loop coil	○				1 MHz to 10 GHz
5.6 Harmonic resonance cavity perturbation	○		○		250 MHz to 18 GHz
		○		○	1,8 MHz

Range of frequency (1 MHz to 6 GHz)

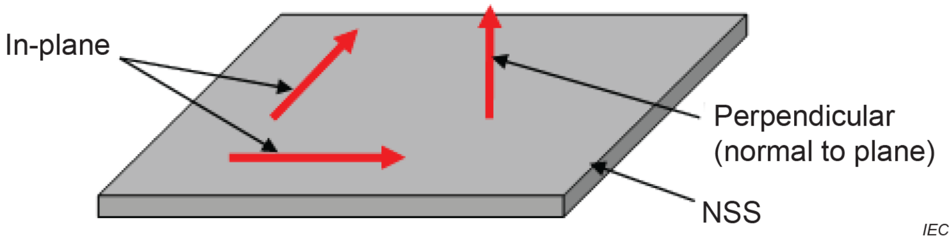


Figure 1 – In-plane and perpendicular measurement direction of NSS sample

5 Measurement methods

5.1 Inductance method

5.1.1 Measurement parameters

The measurement parameters of a magnetic material are defined as follows:

$$\mu_r = \mu_r' - j\mu_r'' \quad (1)$$

where

μ_r' and μ_r'' are the real part and the imaginary part of the complex relative permeability, respectively.

5.1.2 Measurement frequency and accuracy

The objective of this method is to evaluate the in-plane permeability of toroidal-shaped thin NSS samples shown in Figure 2 and is applicable for the measurements under the following conditions:

frequency	:	1 MHz ≤ f ≤ 1 GHz
relative permeability	:	1 ≤ μ_r' ≤ 1 000
		0 ≤ μ_r'' ≤ 1 000
accuracy	:	value error ±20 % for μ_r'
		value error ±20 % for μ_r''

The measurement frequency range is affected by the dimensions and the permeability values of the NSS sample. The higher the permittivity, the lower the upper limit of the frequency range will be.

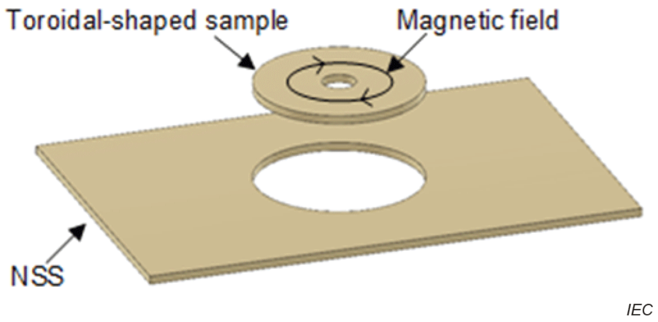


Figure 2 – Toroidal-shaped sample cut from the NSS

5.1.3 Measurement principle

The test fixture shown in Figure 3 forms the ideal one-turn inductor. The self-inductance is given by

$$\frac{Z}{\mathrm{j}\omega} = \frac{1}{I}\int_S B\, ds \tag{2}$$

where

Z is the impedance (Ω);

$\omega = 2\pi f$ is the angular frequency (rad/s);

I is the current (A);

$B = \mu_0 \mu_r H$ is the magnetic flux density (T);

H is the Magnetic field strength (A/m);

μ_0 is the permeability of vacuum ($4\pi \times 10^{-7}$ H/m);

S is the surface shown in Figure 3.

Therefore, the complex relative permeability is

$$\mu_r = \frac{2\pi}{\mu_0}\frac{Z_m - Z_{sm}}{\mathrm{j}\omega F} + 1 = \frac{2\pi}{\mu_0}\frac{Z_{NSS}}{\mathrm{j}\omega F} + 1 \tag{3}$$

or

$$\mu_r' = \frac{2\pi}{\mu_0}\frac{x_m - x_{sm}}{\omega F} + 1 = \frac{2\pi}{\mu_0}\frac{x_{NSS}}{\omega F} + 1 \tag{4}$$

$$\mu_r'' = \frac{2\pi}{\mu_0}\frac{r_m - r_{sm}}{\omega F} = \frac{2\pi}{\mu_0}\frac{r_{NSS}}{\omega F} \tag{5}$$

where

$Z_m = r_m + \mathrm{j}x_m$ is the measured impedance with a sample;

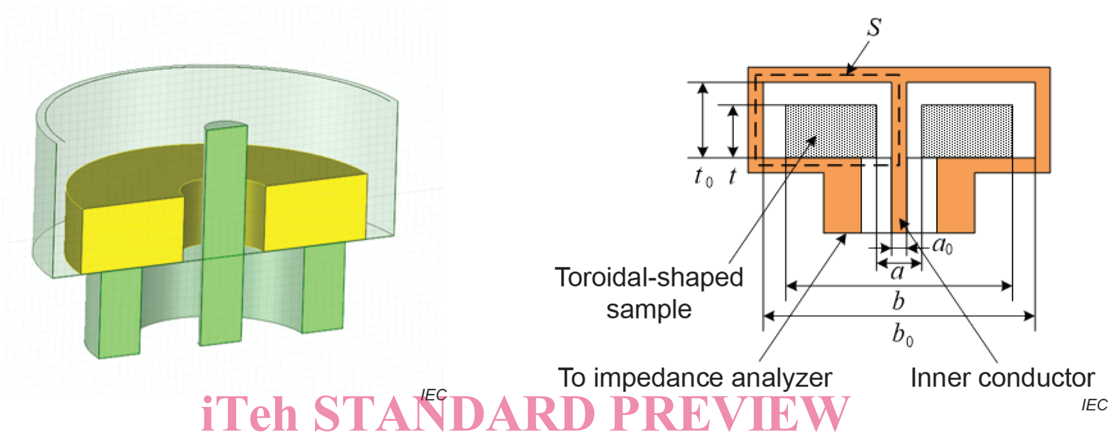
$Z_{sm} = r_{sm} + \mathrm{j}x_{sm}$ is the measured impedance without a sample (in short state);

$Z_{NSS} = r_{NSS} + \mathrm{j}x_{NSS}$ is the impedance of a NSS sample;

$F = t\ln\left(\frac{b}{a}\right)$ is the shape factor of a sample, inner diameter a, outer diameter b, and thickness t.

Z_{sm} is used to minimize errors due to residual impedance by compensation. The equivalent circuit model of the test fixture is shown in Figure 4. g_p + jb_p is the admittance of the test fixture and its effect can be neglected in a simplified case. Therefore, the impedance Z_{NSS} of a NSS sample is $Z_m - Z_{sm}$.

The derivation procedure is shown in detail in Annex A.



a) Structure b) Parameters

Figure 3 – Test fixture with a toroidal-shaped NSS sample

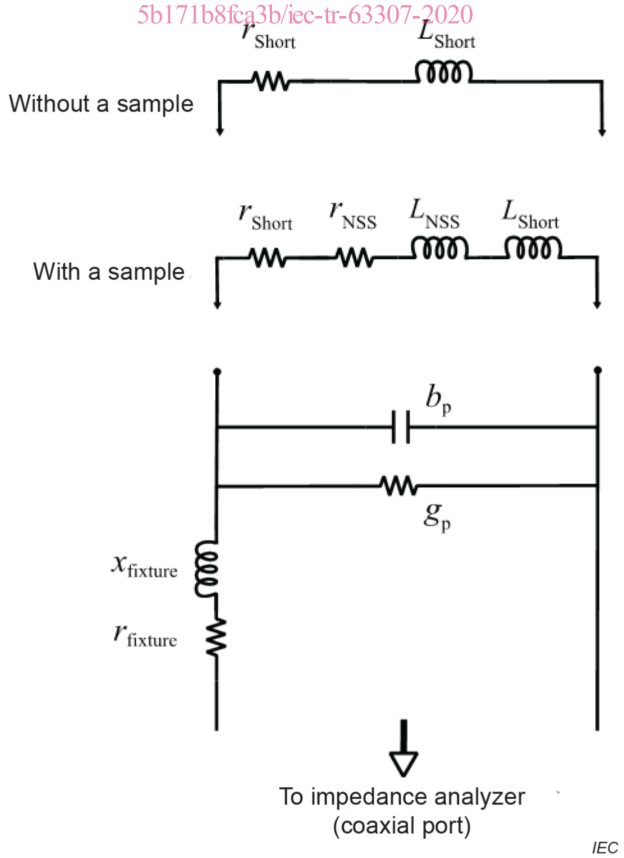


Figure 4 – Equivalent circuit model of the test fixture