IEC 61189-2-721

Edition 1.0 2015-04

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Test methods for electrical materials, printed boards and other interconnection structures and assemblies –
Part 2-721: Test methods for materials for interconnection structures – Measurement of relative permittivity and loss tangent for copper clad laminate at microwave frequency using split post dielectric resonator

Méthodes d'essai pour les matériaux électriques, les cartes imprimées et autres structures d'interconnexion et ensembles –
Partie 2-721: Méthodes d'essai des matériaux pour structures d'interconnexion – Mesure de la permittivité relative et de la tangente de perte pour les stratifiés recouverts de cuivre en hyperfréquences à l'aide d'un résonateur diélectrique en anneaux fendus

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The text of this standard is based on the following documents:

FDIS	Report on voting
91/1246/FDIS	91/1258/RVD

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

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Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

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TEST METHODS FOR ELECTRICAL MATERIALS, PRINTED BOARDS AND OTHER INTERCONNECTION STRUCTURES AND ASSEMBLIES –

Part 2-721: Test methods for materials for interconnection structures – Measurement of relative permittivity and loss tangent for copper clad laminate at microwave frequency using split post dielectric resonator

1 Scope

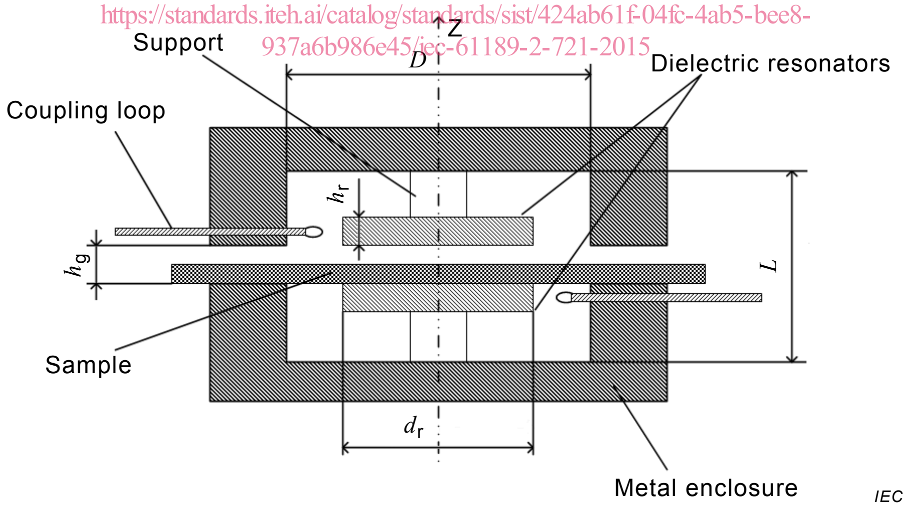
This part of IEC 61189 outlines a way to determine the relative permittivity (ε_r) and loss tangent (tanδ) (also called dielectric constant (*Dk)* and dissipation factor (*Df*)) of copper clad laminates at microwave frequencies (from 1,1 GHz to 20 GHz) using a split post dielectric resonator (SPDR).

This part of IEC 61189 is applicable to copper clad laminates and dielectric base materials.

2 Test specimens

2.1 Specimen size

The size of the specimen shall be larger than the internal diameter D of the metal enclosures, and the maximum thickness of the specimen shall be smaller than the distance h_g between the metal enclosures of the fixture. (See Figure 1.)



Key

h_g distance between the metal enclosures of the fixture;

D internal diameter of the metal enclosures;

L internal height of the metal enclosures;

d_r diameter of the dielectric resonator;

h_r thickness of the dielectric resonator.

Figure 1 – Scheme of SPDR test fixture

Three specimens for the test at room temperature and one specimen for the test at variable temperatures are required for each SPDR test fixture for this test. Table 1 shows the supported specimen dimensions.

Table 1 – Specimen dimensions

SPDR test fixture's nominal frequency GHz	Supported specimen sizes mm	Maximum thickness of specimens mm
1,1	150 × 150	6,0
3	80 × 80	3,0
5 to 6	80 × 80	2,0
9 to 10	80 × 80	0,9
13 to 16	50 × 35	0,6
18 to 20	15 × 15	0,5

If applicable, a specimen size different from those given in Table 1 can be used. For example, specimen size "130 mm × 130 mm" can be used for 1,1 GHz.

2.2 Preparation

Copper clad laminates shall have all copper cladding removed by etching, and shall be thoroughly cleaned.

2.3 Marking

Mark each specimen in the upper left corner with an engraving pencil or other suitable method.

2.4 Thickness

Within the limits of the test fixture, the thicker the specimen is, the less error occurs in the measurements. Thin specimen can be stacked up to a minimum of 0,4 mm to improve measurement accuracy.

NOTE Air gaps between the sample and fixture do not affect the measurement.

3 Equipment/apparatus

3.1 General

The component diagram of the test system is shown in Figure 2.

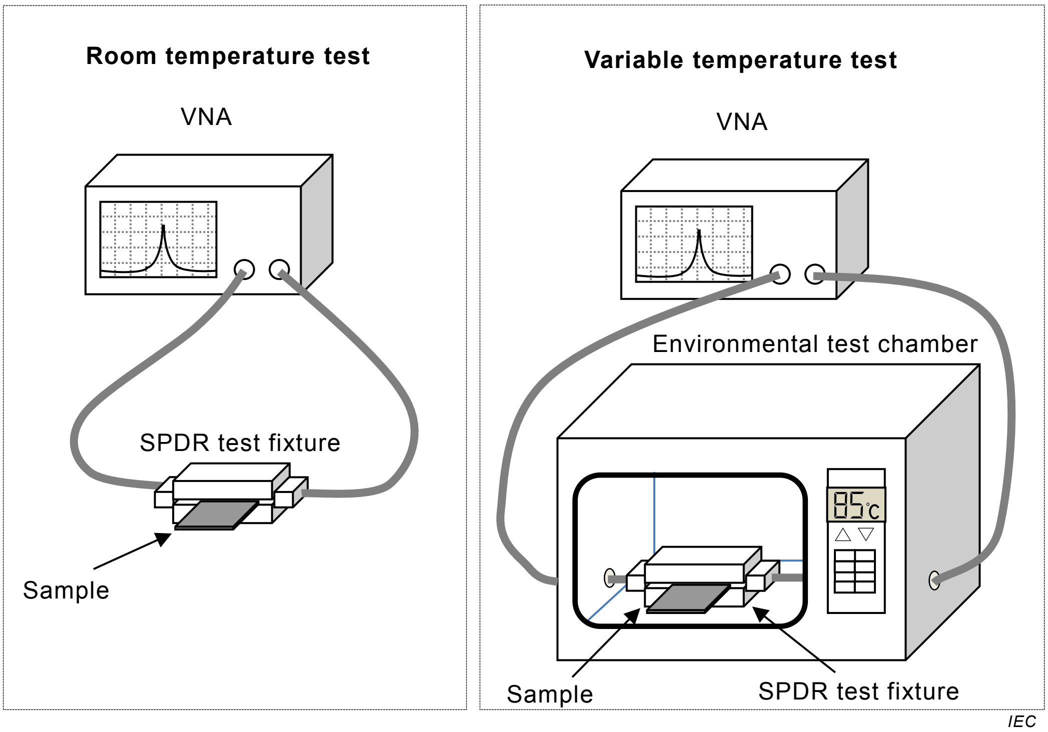


Figure 2 – Component diagram of test system

3.2 Vector network analyzer (VNA)

The following values are required:

a) The frequency range of VNA shall be 500 MHz to 20 GHz.

b) The dynamic range of VNA shall be more than 60 dB.

3.3 SPDR test fixture

3.3.1 General

Figure 1 shows the scheme of SPDR test fixture.

3.3.2 Parameters

Table 2 shows the typical relationship between the SPDR test fixture’s nominal frequency and h_g and D.

3.3.3 Frequency

For different test frequencies, use a corresponding SPDR test fixture of nominal frequency.

Table 2 – SPDR test fixture's parameter

SPDR test fixture's nominal frequency GHz	D mm	h_g mm
1,1	120	6,0
3	50	3,0
5 to 6	30	2,0
9 to 10	22	0,9
13 to 16	15	0,6
18 to 20	10	0,5

3.4 Verify unit

The verify unit includes the following:

a) Standard reference sample, for example, single-crystal quartz or equivalent sample.

b) A calibration assembly of VNA.

3.5 Micrometer

Micrometer with 0,001 mm resolution (or better).

3.6 Circulating oven

Circulating oven with stabilized temperature at 105^{+5}_{-2} °C.

3.7 Test chamber

For the environmental test chamber for variable temperature testing the following requirements apply:

a) Temperature ranges: –125 °C to +110 °C, other temperature range is as agreed between user and supplier.

b) Temperature accuracy-set point to actual: ±1 °C.

4 Procedure

4.1 Preconditioning

All specimens shall be conditioned at (23 ± 2) °C and (50 ± 5) % RH for at least 24 h prior to testing. However, if a specimen has recently been etched or exposed to excessive moisture, it should be dried in an air-circulating oven for 2 h at 105^{+5}_{-2} °C and then conditioned at the condition as mentioned above.

4.2 Testing of relative permittivity and loss tangent at room temperature

4.2.1 Test conditions

The ambient test temperature should be (23 ± 2) °C. The variation should not exceed 1 °C during the test.

4.2.2 Preparation

Allow at least 30 min for the VNA to warm up and stabilize.

4.2.3 Fixture

Select an SPDR test fixture in accordance with the test frequency. The specimen size and thickness shall comply with the requirements specified in Table 1. For example, if the test frequency is 10 GHz, a SPDR test fixture with 10 GHz nominal frequency should be selected. The supported specimen size is 80 mm × 80 mm and the maximum thickness of specimens is no more than 0,9 mm.

4.2.4 Connection to VNA

Connect the SPDR test fixture to the VNA. The test fixture shall be kept horizontal.

4.2.5 VNA parameter

Set the VNA parameters according to the manufacturer's instructions and the nominal frequency of the SPDR fixture.

4.2.6 Frequency and Q-factor without specimen

Measure the resonance frequency (f_0) and Q-factor (Q_0) values of the empty resonator.

4.2.7 Micrometer

Utilize a micrometer to measure the thickness of the specimen and record as h.

4.2.8 Setting the specimen

Insert the specimen into the test fixture. The side with marking is face up and the edge of this side has to be aligned with the fixture edge.

4.2.9 Frequency and Q-factor with specimen

Measure the resonance frequency (f_s) and Q-factor (Q_s) of the resonator containing the specimen.

4.2.10 Comparison

The scheme of the change of resonance frequency with or without the specimen is shown in Figure 3.

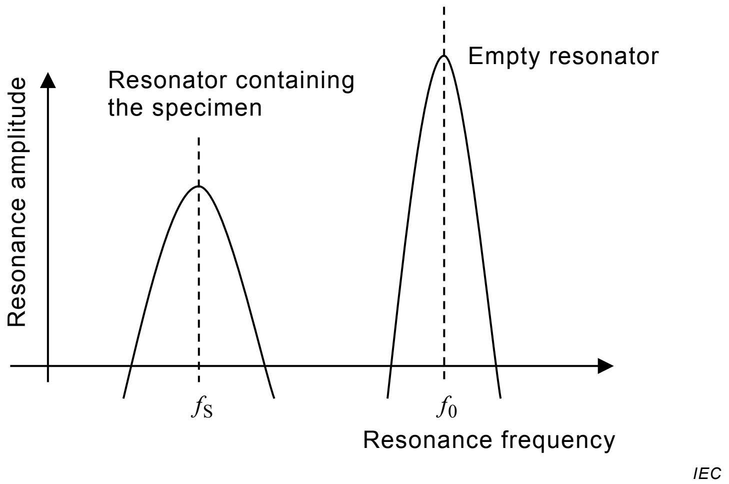


Figure 3 – Scheme of the change of resonance frequency with or without the specimen

4.2.11 Calculation

4.2.11.1 General

Calculation of relative permittivity and loss tangent at room temperature.

Relative permittivity and loss tangent at room temperature shall be calculated as follows. It is recommended to use the computer software provided by the equipment supplier for calculation.

4.2.11.2 Relative permittivity

The relative permittivity (ε_r) shall be calculated according to Equation (1).

$$\varepsilon_r = 1 + \frac{f_0 - f_s}{h f_0 K_\varepsilon(\varepsilon_r, h)} \tag{1}$$

where

ε_r is relative permittivity;

h is the thickness of the specimen under test, in mm;

f_0 is the resonant frequency of the empty SPDR;

f_s is the resonant frequency of the resonator with the dielectric specimen;

$K_\varepsilon(\varepsilon_r, h)$ is a function of ε_r and h. For a fixed resonant cavity, its physical parameters (size, dielectric resonators ε_r) should have been identified. $K_\varepsilon(\varepsilon_r, h)$ is pre-computed and tabulated by electromagnetic field simulation with the strict Rayleigh-Ritz method. Put the empty SPDR frequency (f_0), the resonant frequency with dielectric specimen (f_s) and the thickness of the specimen (h) under test into Equation (1). Enter a similar arbitrary value of the relative permittivity of the sample, and use a successive approximation algorithm. After several iterations, end the calculation when the relative error of the last two calculated relative permittivities is less than 0,1 %. The last calculated data is taken as the relative permittivity of the specimen. Some additional information is shown in Annex B.

4.2.11.3 Loss tangent

The loss tangent shall be calculated according to Equation (2).

$$\tan\delta = \frac{\left(Q_S^{-1} - Q_{DR}^{-1} - Q_C^{-1}\right)}{p_{es}} \tag{2}$$

where

$\tan\delta$ is the loss tangent;

Q_s is the unloaded Q-factor of a resonant fixture containing the specimen;

Q_c is the Q-factor depending on metal losses for the resonant fixture containing the specimen;

Q_{DR} is the Q-factor depending on dielectric losses in the dielectric posts for the fixture containing the specimen;

p_{es} is the electromagnetic energy filling factor of the specimen. After identifying the physical parameters of the resonant cavity, the electromagnetic energy filling factor p_{es} can be determined by electromagnetic field simulation. For a fixed resonant cavity, p_{es} is a constant value. Some additional information is showed in Annex B.