SLOVENSKI STANDARD

SIST EN 62562:2011

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Metoda z votlinskim resonatorjem za merjenje kompleksne permitivnosti nizkoizgubnih dielektričnih plošč (IEC 62562:2010)

Cavity resonator method to measure the complex permittivity of low-loss dielectric plates (IEC 62562:2010)

Hohlraumresonanzverfahren zum Messen der komplexen Permittivität von verlustarmen dielektrischen Platten (IEC 62562:2010)

Méthode de la cavité résonante pour mesurer la permittivité complexe des plaques diélectriques à faibles pertes (CEI 62562:2010)

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Cavity resonator method to measure the complex permittivity of low-loss dielectric plates
(IEC 62562:2010)

Méthode de la cavité résonante pour mesurer la permittivité complexe des plaques diélectriques à faibles pertes
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Hohlraumresonanzverfahren zum Messen der komplexen Permittivität von verlustarmen dielektrischen Platten
(IEC 62562:2010)

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CENELEC

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Foreword

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The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2011-10-02
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IEC 62562

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INTERNATIONAL STANDARD

colour inside

Cavity resonator method to measure the complex permittivity of low-loss dielectric plates

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CONTENTS

FOREWORD ... 3
1 Scope ... 5
2 Measurement parameters ... 5
3 Theory and calculation equations ... 6
3.1 Relative permittivity and loss tangent ... 6
3.2 Temperature dependence of ε' and $\tan\delta$ ... 9
3.3 Cavity parameters ... 10
4 Measurement equipment and apparatus ... 11
4.1 Measurement equipment ... 11
4.2 Measurement apparatus for complex permittivity ... 11
5 Measurement procedure ... 12
5.1 Preparation of measurement apparatus ... 12
5.2 Measurement of reference level ... 12
5.3 Measurement of cavity parameters: D, H, σ_r, α_c, $TC\rho$ ... 12
5.4 Measurement of complex permittivity of test specimen: ε', $\tan\delta$ ... 14
5.5 Temperature dependence of ε' and $\tan\delta$ ... 15
Annex A (informative) Example of measured result and accuracy ... 16
Bibliography ... 20

Figure 1 – Resonator structures of two types ... 6
Figure 2 – Correction term $\Delta\varepsilon'/\varepsilon'_a$ ... 9
Figure 3 – Correction terms $\Delta A/A$ and $\Delta B/B$ ... 9
Figure 4 – Schematic diagram of measurement equipments ... 11
Figure 5 – Cavity resonator used for measurement ... 12
Figure 6 – Photograph of cavity resonator for measurement around 10 GHz ... 12
Figure 7 – Mode chart of cavity resonator ... 13
Figure 8 – Resonance peaks of cavity resonator ... 13
Figure 9 – Resonance frequency f_0, insertion attenuation IA_0 and half-power band width f_{BW} ... 14
Figure 10 – Resonance frequency f_0 of TE_{011} mode of cavity resonator with dielectric plate (D = 35 mm, H = 25 mm) ... 15
Figure A.1 – Measured temperature dependence of f_1 and Q_{uc} ... 17
Figure A.2 – Resonance peaks of cavity resonator clamping sapphire plate ... 18
Figure A.3 – Measured results of temperature dependence of f_0, Q_u, ε' and $\tan\delta$ for sapphire plate ... 19

Table A.1 – Measured results of cavity parameters ... 16
Table A.2 – Measured results of of ε' and $\tan\delta$ for sapphire plate ... 18

INTERNATIONAL ELECTROTECHNICAL COMMISION

CAVITY RESONATOR METHOD TO MEASURE THE COMPLEX PERMITTIVITY OF LOW-LOSS DIELECTRIC PLATES

FOREWORD

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International Standard IEC 62562 has been prepared by subcommittee 46F: R.F. and microwave passive components, of IEC technical committee 46: Cables, wires, waveguides, R.F. connectors, R.F. and microwave passive components and accessories.

This first edition cancels and replaces the PAS published in 2008.

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

CDV	Report on voting
46F/118/CDV	46F/143/RVC

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

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

The committee has decided that the contents of this publication 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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CAVITY RESONATOR METHOD TO MEASURE THE COMPLEX PERMITTIVITY OF LOW-LOSS DIELECTRIC PLATES

1 Scope

The object of this International Standard is to describe a measurement method of dielectric properties in the planar direction of dielectric plate at microwave frequency. This method is called a cavity resonator method. It has been created in order to develop new materials and to design microwave active and passive devices for which standardization of measurement methods of material properties is more and more important.

This method has the following characteristics:

- the relative permittivity ε' and loss tangent $\tan\delta$ values of a dielectric plate sample can be measured accurately and non-destructively;
- temperature dependence of complex permittivity can be measured;
- the measurement accuracy is within 0,3 % for ε' and within 5×10^{-6} for $\tan\delta$;
- fringing effect is corrected using correction charts calculated on the basis of rigorous analysis.

This method is applicable for the measurements on the following condition:

– frequency : 2 GHz < f < 40 GHz;

– relative permittivity: 2 < ε' < 100;

– loss tangent : 10^{-6} < $\tan\delta$ < 10^{-2}.

2 Measurement parameters

The measurement parameters are defined as follows:

$$\varepsilon_r = \varepsilon' - j\varepsilon'' = D/(\varepsilon_0 E) \tag{1}$$

$$\tan\delta = \varepsilon''/\varepsilon' \tag{2}$$

$$TC\varepsilon = \frac{1}{\varepsilon_{\text{ref}}}\frac{\varepsilon_T - \varepsilon_{\text{ref}}}{T - T_{\text{ref}}}\times10^6 \qquad (1\times10^{-6}/\text{K}) \tag{3}$$

where

D	is the electric flux density;
E	is the electric field strength;
ε_0	is the permittivity in a vacuum;
ε' and ε''	are the real and imaginary components of the complex relative permittivity ε_r;
$TC\varepsilon$	is the temperature coefficient of relative permittivity;
ε_T and ε_{ref}	are the real parts of the complex relative permittivity at temperature T and reference temperature T_{ref} (= 20 °C to 25 °C), respectively.

3 Theory and calculation equations

3.1 Relative permittivity and loss tangent

A resonator structure used in the nondestructive measurement of the complex permittivity is shown in Figure 1a.

A cavity having diameter D and length $H = 2M$ is cut into two halves in the middle of its length.

A dielectric plate sample having ε', $\tan\delta$ and thickness t is placed between these two halves.

The TE_{011} mode, having only the electric field component tangential to the plane of the sample, is used for the measurement, since air gaps at the plate-cavity interfaces do not affect the electromagnetic field. Taking account of the fringing field in the plate region outside diameter of the cavity on the basis of the rigorous mode matching analysis, we determine ε' and $\tan\delta$ from the measured values of the resonant frequency f_0 and the unloaded Q-factor Q_u. This numerical calculation, however, is rather tedious.

Therefore,

a) approximated values ε'_a and $\tan\delta_a$ from the f_0 and Q_u values by using simple formula for a resonator structure shown in Figure 1b, where a fringing effect for Figure 1a is neglected, will be determined;

b) then, accurate values ε' and $\tan\delta$ from ε'_a and $\tan\delta_a$ using charts calculated from the rigorous analysis will be obtained.

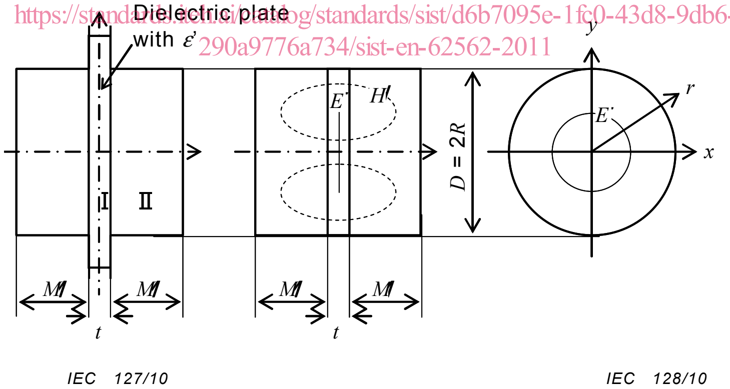

Figure 1a – Resonator used in measurement **Figure 1b – Resonator to calculate ε'_a and $\tan\delta_a$**

Figure 1 – Resonator structures of two types

The value of ε'_a is given by

$$\varepsilon'_a = \left(\frac{c}{\pi t f_0}\right)^2 \left\{ X^2 - Y^2 \left(\frac{t}{2M}\right)^2 \right\} + 1 \qquad (4)$$

where c is the velocity of light in a vacuum ($c = 2{,}997\,9 \times 10^8$ m/s) and the first root X is calculated from a given value Y, using the following simultaneous equations:

$$X \tan X = \frac{t}{2M} Y \cot Y \qquad (5)$$

$$Y = M\sqrt{k_0{}^2 - k_r{}^2} = jY' \qquad (6)$$

with $k_0 = 2\pi f_0/c$, $k_r = j'_{01}/R$, and $j'_{01} = 3{,}83173$ for the TE_{011} mode. When $k_0 - k_r < 0$, Y is replaced by jY'.

The value of $\tan\delta_a$ is given by

$$\tan\delta_a = \frac{A}{Q_u} - R_s B \qquad (7)$$

where R_s is the surface resistance of the conductor of cavity, given by

$$R_s = \sqrt{\frac{\pi f_0 \mu}{\sigma}} \text{ (1/S)}, \quad \sigma = \sigma_0 \sigma_r \text{ (S/m)} \qquad (8)$$

Here, μ and σ are the permeability and conductivity of the conductor. Furthermore, σ_r is the relative conductivity and $\sigma_0 = 5{,}8 \times 10^7$ S/m is the conductivity of standard copper. Constants A and B are given by

$$A = 1 + \frac{W_2^e}{W_1^e} \qquad (9)$$

$$B = \frac{P_{cy1} + P_{cy2} + P_{end}}{\omega R_s W_1^e} \qquad (10)$$

In the above, $W_1{}^e$ and $W_2{}^e$ are electric field energies stored in the dielectric plate of region 1 and air of region 2 shown in Figure 1a. Furthermore, P_{cy1}, P_{cy2} and P_{end} are the conductor loss at the cylindrical wall in the region 1, 2 and at the end wall. These parameters are given by

$$W_1^e = \frac{\pi}{8} \varepsilon_0 \varepsilon'_a \mu_0^2 \omega^2 j_{01}'^2 J_0^2(j_{01}') t \left(1 + \frac{\sin 2X}{2X}\right) \qquad (11)$$

$$W_2^e = \frac{\pi}{4} \varepsilon_0 \mu_0^2 \omega^2 j_{01}'^2 J_0^2(j'_{01}) M \left(1 - \frac{\sin 2Y}{2Y}\right) \frac{\cos^2 X}{\sin^2 Y} \qquad (12)$$

$$P_{cy1} = \frac{\pi}{4} R_s J_0^2(j'_{01}) t R k_r{}^4 \left(1 + \frac{\sin 2X}{2X}\right) \qquad (13)$$

$$P_{cy2} = \frac{\pi}{2} R_s J_0^2(j'_{01}) M R k_r{}^4 \left(1 - \frac{\sin 2Y}{2Y}\right) \frac{\cos^2 X}{\sin^2 Y} \qquad (14)$$