

DD IEC/PAS 62562:2008



BSI Standards Publication

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

bsi.

...making excellence a habit.
AVA Documents™
Document Sharing Hub

National foreword

This Draft for Development is the UK implementation of IEC/PAS 62562:2008.

This publication is not to be regarded as a British Standard.

It is being issued in the Draft for Development series of publications and is of a provisional nature. It should be applied on this provisional basis, so that information and experience of its practical application can be obtained.

A PAS is a Technical Specification not fulfilling the requirements for a standard, but made available to the public and established in an organization operating under a given procedure.

A review of this Draft for Development will be carried out not later than three years after its publication.

Notification of the start of the review period, with a request for the submission of comments from users of this Draft for Development, will be made in an announcement in the appropriate issue of Update Standards. According to the replies received, the responsible BSI Committee will judge whether the validity of the PAS should be extended for a further three years or what other action should be taken and pass their comments on to the relevant international committee.

Observations which it is felt should receive attention before the official call for comments will be welcomed. These should be sent to the Secretary of the responsible BSI Technical Committee at British Standards House, 389 Chiswick High Road, London W4 4AL.

The UK participation in its preparation was entrusted by Technical Committee EPL/46, Cables, wires and waveguides, radio frequency connectors and accessories for communication and signalling, to Subcommittee EPL/46/2, Radio frequency connectors and waveguides.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© BSI 2009

ISBN 978 0 580 62052 2

ICS 17.220.20; 33.120.01

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 January 2009.

Amendments issued since publication

Amd. No.	Date	Text affected
----------	------	---------------

CONTENTS

FOREWORD.....	3
1 Scope.....	4
2 Measurement parameters.....	4
3 Theory and calculation equations.....	5
3.1 Relative permittivity and loss tangent.....	5
3.2 Temperature dependence of ε' and $\tan \delta$	7
3.3 Cavity parameters.....	8
4 Measurement equipment and apparatus.....	9
4.1 Measurement equipment.....	9
4.2 Measurement apparatus for complex permittivity.....	9
5 Measurement procedure.....	10
5.1 Preparation of measurement apparatus.....	10
5.2 Measurement of reference level.....	10
5.3 Measurement of cavity parameters: D , H , σ_r , α_c , $TC\rho$	10
5.4 Measurement of complex permittivity of test specimen: ε' , $\tan \delta$	12
5.5 Temperature dependence of ε' and $\tan \delta$	13
Annex A (informative) Example of measured result and accuracy.....	14
A.1 Cavity parameters.....	14
A.2 Relative permittivity ε' and loss tangent $\tan \delta$	15
A.3 Measurement accuracy.....	16
Bibliography.....	17
Figure 1 – Resonator structures of two types.....	5
Figure 2 – Correction term $\Delta\varepsilon'/\varepsilon'_a$	7
Figure 3 – Correction terms $\Delta A/A$ and $\Delta B/B$	7
Figure 4 – Schematic diagram of measurement equipments.....	9
Figure 5 – Cavity resonator used for measurement.....	10
Figure 6 – Photograph of cavity resonator for measurement around 10 GHz.....	10
Figure 7 – Mode chart of cavity resonator.....	11
Figure 8 – Resonance peaks of cavity resonator.....	11
Figure 9 – Resonance frequency f_0 , insertion attenuation IA_0 and half-power band width f_{BW}	12
Figure 10 – Resonance frequency f_0 of TE_{011} mode of cavity resonator with dielectric plate ($D = 35$ mm, $H = 25$ mm).....	12
Figure A.1 – Measured temperature dependence of f_1 and Q_{UC}	14
Figure A.2 – Resonance peaks of cavity resonator clamping sapphire plate.....	15
Figure A.3 – Measured results of temperature dependence of f_0 , Q_u , ε' and $\tan \delta$ for sapphire plate.....	16
Table A.1 – Measured results of cavity parameters.....	14
Table A.2 – Measured results of ε' and $\tan \delta$ for sapphire plate.....	15

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

A PAS is a technical specification not fulfilling the requirements for a standard but made available to the public.

IEC-PAS 62562 has been processed by subcommittee 46F: RF and microwave passive components, of IEC technical committee 46: Cables, wires, waveguides, r.f. connectors, r.f. and microwave passive components and accessories.

The text of this PAS is based on the following document:

This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document

Draft PAS	Report on voting
46F/73/NP	46F/78/RVN

Following publication of this PAS, which is a pre-standard publication, the technical committee or subcommittee concerned will transform it into an International Standard.

This PAS shall remain valid for an initial maximum period of three years starting from 2008-01. The validity may be extended for a single three-year period, following which it shall be revised to become another type of normative document or shall be withdrawn.

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

1 Scope

This PAS describes the measurement method of dielectric properties in the planer direction of dielectric plate at microwave frequency in order to develop new materials and to design microwave active and passive devices. This method is called a cavity resonator method.

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 measurements in the following conditions:

- frequency : $2 \text{ GHz} < f < 40 \text{ GHz}$;
- relative permittivity : $2 < \varepsilon' < 100$;
- loss tangent : $10^{-6} < \tan \delta < 10^{-2}$.

2 Measurement parameters

The measurement parameters are defined as follows.

$$\varepsilon_r = \varepsilon' - j\varepsilon'' = D/(\varepsilon_0 E) \quad (1)$$

$$\tan \delta = \varepsilon'' / \varepsilon' \quad (2)$$

$$TC\varepsilon = \frac{1}{\varepsilon_{ref}} \frac{\varepsilon_T - \varepsilon_{ref}}{T - T_{ref}} \times 10^6 \quad (1 \times 10^{-6}/K) \quad (3)$$

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} ($= 20^\circ\text{C}$ to 25°C), respectively.

3 Theory and calculation equations

3.1 Relative permittivity and loss tangent

A resonator structure used in the non-destructive 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 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, we first determine approximate 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 the fringing effect for Figure 1a is neglected. Then, we obtain accurate values ε' and $\tan \delta$ from ε'_a and $\tan \delta_a$ using charts calculated from the rigorous analysis.

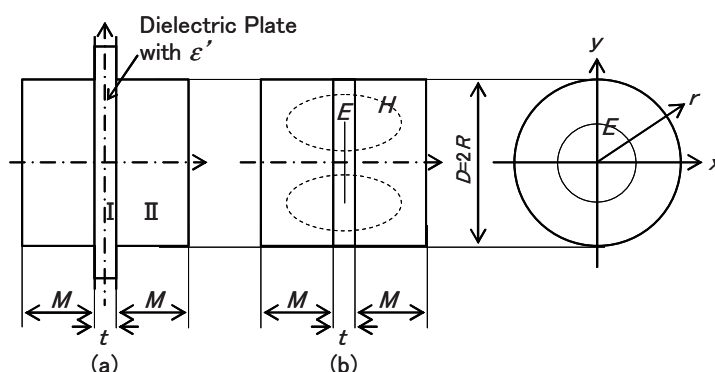


Figure 1a – Resonator used in measurement

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

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

where c is the velocity of light in a vacuum ($c = 2,9979 \times 10^8$ m/s) and the first root X is calculated from a given value Y , using the following simultaneous equations:

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

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

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

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

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