INTERNATIONAL STANDARD

IEC 61338-1-4

First edition
2005-11

Waveguide type dielectric resonators –

Part 1-4:
General information and test conditions – Measurement method of complex relative permittivity for dielectric resonator materials at millimetre-wave frequency

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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WAVEGUIDE TYPE DIELECTRIC RESONATORS –

Part 1-4: General information and test conditions – Measurement method of complex relative permittivity for dielectric resonator materials at millimetre-wave frequency

FOREWORD

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International Standard IEC 61338-1-4 has been prepared by IEC Technical committee 49: Piezoelectric and dielectric devices for frequency control and selection.

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

FDIS	Report on voting
49/748/FDIS	49/751/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.

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

IEC 61338 consists of the following parts, under the general title *Waveguide type dielectric resonators:*

Part 1: Generic specification

Part 1-3: General information and test conditions – Measurement method of complex relative permittivity for dielectric resonator materials at microwave frequency

Part 1-4: General information and test conditions – Measurement method of complex relative permittivity for dielectric resonator materials at millimetre-wave frequency

Part 2: Guidelines for oscillator and filter applications

Part 4: Sectional specification

Part 4-1: Blank detail specification

The committee has decided that the contents of this publication will remain unchanged until the maintenance result 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- withdrawn,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.

A bilingual version of this publication may be issued at a later date.

WAVEGUIDE TYPE DIELECTRIC RESONATORS –

Part 1-4: General information and test conditions – Measurement method of complex relative permittivity for dielectric resonator materials at millimetre-wave frequency

1 Scope and object

This part of IEC 61338 describes the measurement method of dielectric properties for dielectric resonator materials at millimetre-wave frequency.

This standard consists of two measurement methods: a) the dielectric rod resonator method excited by NRD-guide (Non-Radiative Dielectric waveguide) and b) the cut-off waveguide method excited by coaxial cables with small loops.

a) The dielectric rod resonator method excited by NRD-guide is similar to the dielectric rod resonator method given in IEC 61338-1-3. This method has the following characteristics:
   - a complete and exact mathematical solution of complex permittivity is given by computer software;
   - the measurement error is less than 0,3 % for ε' and less than 0,05 $\times 10^{-4}$ for tan δ;
   - the applicable measuring ranges of complex permittivity for this method are as follows:

     frequency: 30 GHz < f < 100 GHz;

     relative permittivity: 2 < ε' < 30;

     loss factor: 10^{-6} < tan δ < 10^{-2}.

b) The cut-off waveguide method excited by coaxial cables with small loops uses a dielectric plate sample placed in a circular cylinder of the TE_{011} mode. This method has the following characteristics:
   - fringe effect is corrected using the correction charts on the basis of rigorous analysis;
   - the measurement error is less than 0,5 % for ε' and less than 0,05$\times 10^{-4}$ for tan δ;
   - the TCF is measured with high accuracy;
   - the applicable measuring ranges of dielectric properties for this method are as follows:

     frequency: 30 GHz < f < 100 GHz;

     relative permittivity: 2 < ε' < 30;

     loss factor: 10^{-6} < tan δ < 10^{-2}.

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 amendments) applies.

IEC 61338-1-3, *Waveguide type dielectric resonators – Part 1-3: General information and test conditions – Measurement method of complex relative permittivity for dielectric resonator materials at microwave frequency*

3 Measurement parameter

The measuring parameters are defined as follows:

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

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

$$TC\varepsilon = \frac{1}{\varepsilon_{\text{ref}}} \frac{\varepsilon_{\text{T}} - \varepsilon_{\text{ref}}}{T - T_{\text{ref}}} \times 10^6 \qquad (1\times10^{-6}/\text{K}) \tag{3}$$

$$TCF = \frac{1}{f_{\text{ref}}} \frac{f_T - f_{\text{ref}}}{T - T_{\text{ref}}} \times 10^6 \qquad (1\times10^{-6}/\text{K}) \tag{4}$$

where

D is the electric flux density;

E is the electric field strength;

ε_0 is the permittivity in a vacuum;

$\dot{\varepsilon}_r$ is the complex relative permittivity;

ε' and ε'' are the real and imaginary components of the complex relative permittivity $\dot{\varepsilon}_r$;

$TC\varepsilon$ is the temperature coefficient of relative permittivity, and TCF being the temperature coefficient of resonance frequency;

ε_{T} and ε_{ref} are the real parts of the complex relative permittivity at temperature T and reference temperature T_{ref} (T_{ref} = 20 °C to 25 °C), respectively;

f_{T} and f_{ref} are the resonance frequency at temperature T and T_{ref}, respectively.

The TCF is related to $TC\varepsilon$ by the following equation:

$$TCF = -\frac{1}{2} TC\varepsilon - \alpha \tag{5}$$

where α is the coefficient of thermal expansion of the dielectric specimen.

It should be noted that this equation is satisfied when the 100 % of electro-magnetic energy in the measuring resonance mode is concentrated inside the dielectric specimen. In the actual case, TCF deviates by several 10^{-6}/K from the calculated value, because some portion of electro-magnetic energy is stored outside the dielectric specimen.

4 Dielectric rod resonator method excited by NRD-guide

4.1 Measurement equipment and apparatus

The measurement equipment and apparatus are as follows:

a) Measurement equipment

Figure 1 shows a schematic diagram of the equipment required for millimetre wave measurement. For the measurement of dielectric properties, only the information on the amplitude of transmitted power is needed, that is, the information on the phase of the transmitted power is not required. A scalar network analyzer can be used for the measurement, but a vector network analyzer has an advantage in precision of the measurement data.

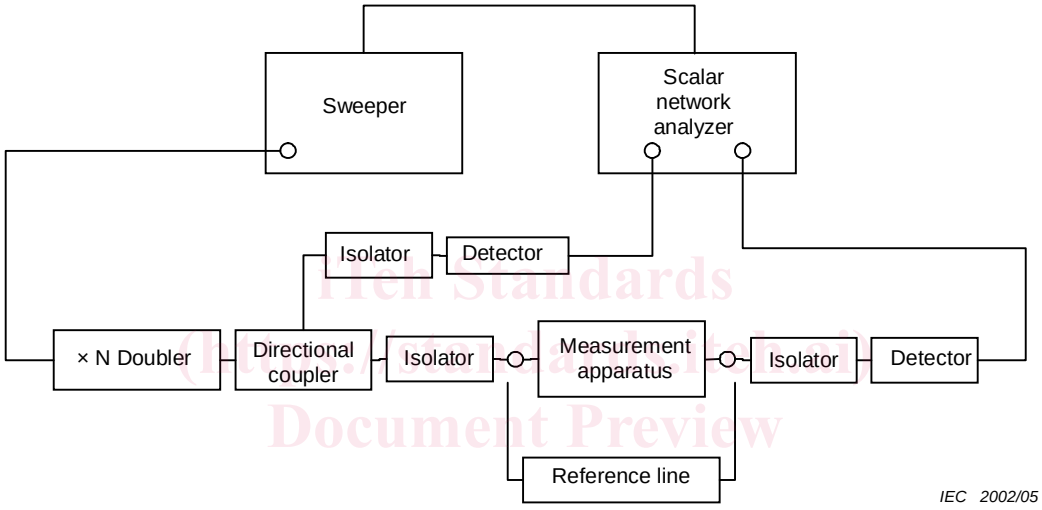

Figure 1a – Scalar network analyzer

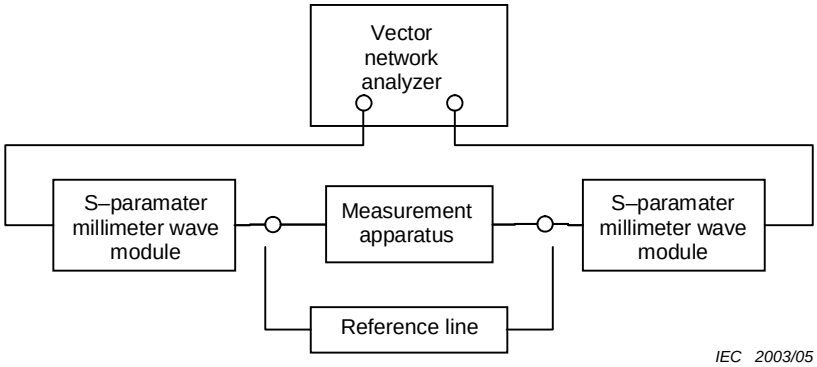

Figure 1b – Vector network analyzer

Figure 1 – Schematic diagram of measurement equipment

b) Measurement apparatus

Figure 2a shows a configuration of measuring apparatus of dielectric rod resonator method excited by NRD-guide. Figure 2b shows a cross-sectional view of the apparatus for measuring ε' and tan δ of a dielectric specimen with height h and d. The dielectric specimen is placed at the centre of the apparatus between two parallel conducting plates, and coupled to input and output NRD-guides. There remains a small air gap Δh between the dielectric specimen and the upper conducting plate. For $\Delta h < 50$ μm, the air gap can be neglected for the calculation of ε' (see Annex A).

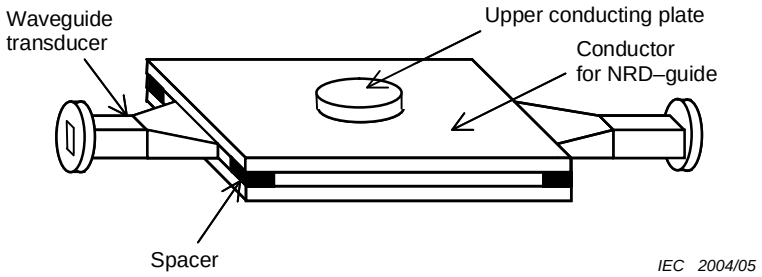

Figure 2a – Configuration of apparatus

Dimensions in millimetres

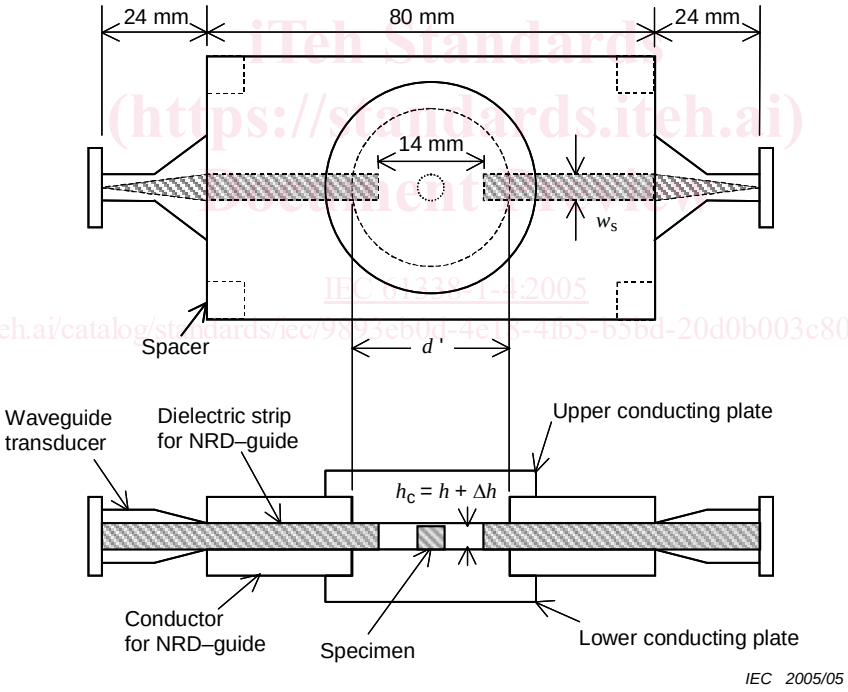

Figure 2b – Apparatus for ε' and tan δ measurement

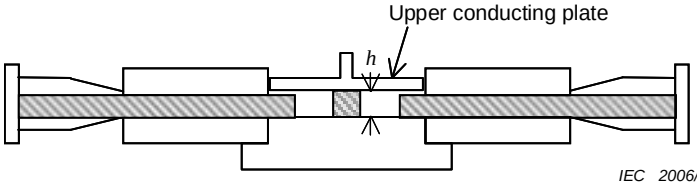

Figure 2c – Apparatus for TCF and $TC\varepsilon$ measurement

Figure 2 – Measurement apparatus of dielectric rod resonator method excited by NRD-guide