

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

The European Standard EN 61338-1-4:2006 has the status of a
British Standard

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National foreword

This British Standard is the UK implementation of EN 61338-1-4:2006, incorporating corrigendum November 2006. It is identical with IEC 61338-1-4:2005.

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

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English version

**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
(IEC 61338-1-4:2005)**

Résonateurs diélectriques
à modes guidés
Partie 1-4: Informations générales
et conditions d'essais -
Méthode de mesure de la permittivité
relative complexe des matériaux
des résonateurs diélectriques fonctionnant
à des fréquences millimétriques
(CEI 61338-1-4:2005)

Dielektrische Resonatoren
vom Wellenleitertyp
Teil 1-4: Allgemeine Informationen
und Prüfbedingungen -
Messverfahren für die komplexe relative
Dielektrizitätskonstante von dielektrischen
Resonatorwerkstoffen im Mikrowellen-
Frequenzbereich
(IEC 61338-1-4:2005)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 49/748/FDIS, future edition 1 of IEC 61338-1-4, prepared by IEC TC 49, Piezoelectric and dielectric devices for frequency control and selection, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61338-1-4 on 2005-12-01.

The following dates were fixed:

- latest date by which the EN has to be implemented
at national level by publication of an identical
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with the EN have to be withdrawn (dow) 2008-12-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61338-1-4:2005 was approved by CENELEC as a European Standard without any modification.

CONTENTS

1	Scope and object.....	5
2	Normative references	5
3	Measurement parameter	6
4	Dielectric rod resonator method excited by NRD-guide	7
4.1	Measurement equipment and apparatus	7
4.2	Theory and calculation equations	10
4.3	Measurement procedure	15
4.4	Example of measurement result	18
5	Cut-off waveguide method excited by coaxial cables with small loops	20
5.1	Measurement equipment and apparatus	20
5.2	Theory and calculation equations	22
5.3	Measurement procedure	27
	Annex A (informative) Errors on ε_r caused by air gap between dielectric specimen and upper conducting plate	29
	Annex B (informative) Derivation of equation (15) for σ_r	30
	Annex ZA (normative) Normative references to international publications with their corresponding European publications.....	33
	Bibliography	32
	Figure 1 – Schematic diagram of measurement equipment	7
	Figure 2 – Measurement apparatus of dielectric rod resonator method excited by NRD-guide.....	8
	Figure 3 – Waveguide transducer from NRD-guide to waveguide	10
	Figure 4 – Configuration of a cylindrical dielectric rod resonator short-circuited at both ends by two parallel conducting plates	11
	Figure 5 –Calculations of u^2 and W as a function of v^2 for TE ₀₁₁ , TE ₀₂₁ and TE ₀₃₁ resonance modes	12
	Figure 6 –Configuration of reference dielectric resonator for measurement of σ_r of conducting plates.....	14
	Figure 7 – Diameter d of TE ₀₁₁ , TE ₀₂₁ and TE ₀₃₁ mode resonators with resonance frequency of 60 GHz	17
	Figure 8 – Diameter d of TE ₀₁₁ , TE ₀₂₁ and TE ₀₃₁ mode resonators with resonance frequency of 77 GHz	18
	Figure 9 – Example of TE ₀₂₁ mode resonant peak	19
	Figure 10 – Measurement result of temperature dependence of f_0 and ε' of sapphire	20
	Figure 11 – Measurement apparatus for cut-off waveguide method	21
	Figure 12 – Frequency response for the empty cavity with dimensions of $d = 7$ mm and $h = 31$ mm	23
	Figure 13 – Correction term $\Delta\varepsilon/\varepsilon_a$	25
	Figure 14 – Correction terms $\Delta A/A$ and $\Delta B/B$	26

Figure 15 – Measurement apparatus for temperature coefficient of relative permittivity	27
Figure 16 – Mode chart of TE_{011} and TE_{013} modes for an empty cavity	28
Figure A.1 – Error on ε' caused by air gap between dielectric specimen and upper conducting plates.....	29
Table 1 – Diameter of conducting plate	9
Table 2 – Dimension of dielectric strip of NRD-guide	9
Table 3 – Dimensions of waveguide transducer	9
Table 4 – Dimensions of reference sapphire resonators and their partial electric energy filling factor P_e and geometric factor G	14
Table 5 – Diameter d of test specimens for 60 and 77 GHz measurement. Height h is fixed to 2,25 mm and 1,80 mm for 60 GHz and 77 GHz measurement, respectively	16
Table 6 – Measurement results of σ_r of conducting plates.....	19
Table 7 – Measurement results of ε' and $\tan \delta$ of sapphire and PTFE specimen	19
Table 8 – Recommended dimensions for conducting cylinder.....	22

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 $\tan \delta$;
 - the applicable measuring ranges of complex permittivity for this method are as follows:

frequency:	$30 \text{ GHz} < f < 100 \text{ GHz}$;
relative permittivity:	$2 < \varepsilon' < 30$;
loss factor:	$10^{-6} < \tan \delta < 10^{-2}$.
- 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 $\tan \delta$;
 - the TCF is measured with high accuracy;
 - the applicable measuring ranges of dielectric properties for this method are as follows:

frequency:	$30 \text{ GHz} < f < 100 \text{ GHz}$;
relative permittivity:	$2 < \varepsilon' < 30$;
loss factor:	$10^{-6} < \tan \delta < 10^{-2}$.

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:

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

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

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

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

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} ($T_{\text{ref}} = 20^\circ\text{C}$ 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:

$$TCF = -\frac{1}{2}TC\varepsilon - \alpha \quad (5)$$

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 $10^{-6}/\text{K}$ 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.

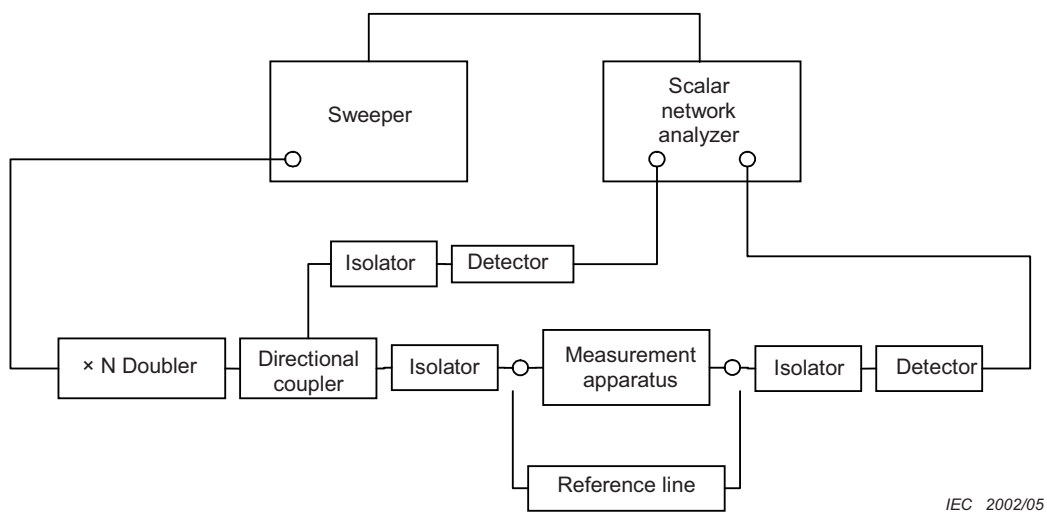


Figure 1a – Scalar network analyzer

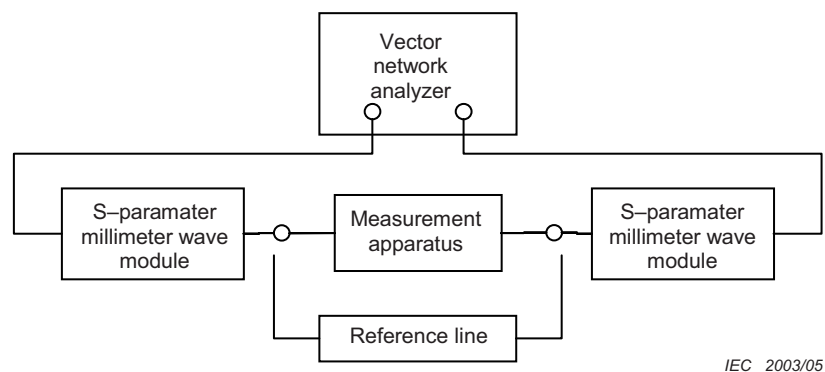


Figure 1b – Vector network analyzer

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 $\tan \delta$ 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 $\Delta h < 50 \mu\text{m}$, the air gap can be neglected for the calculation of ε' (see Annex A).

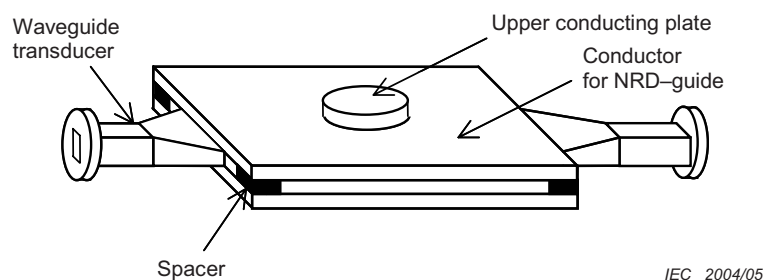


Figure 2a – Configuration of apparatus

Dimensions in millimetres

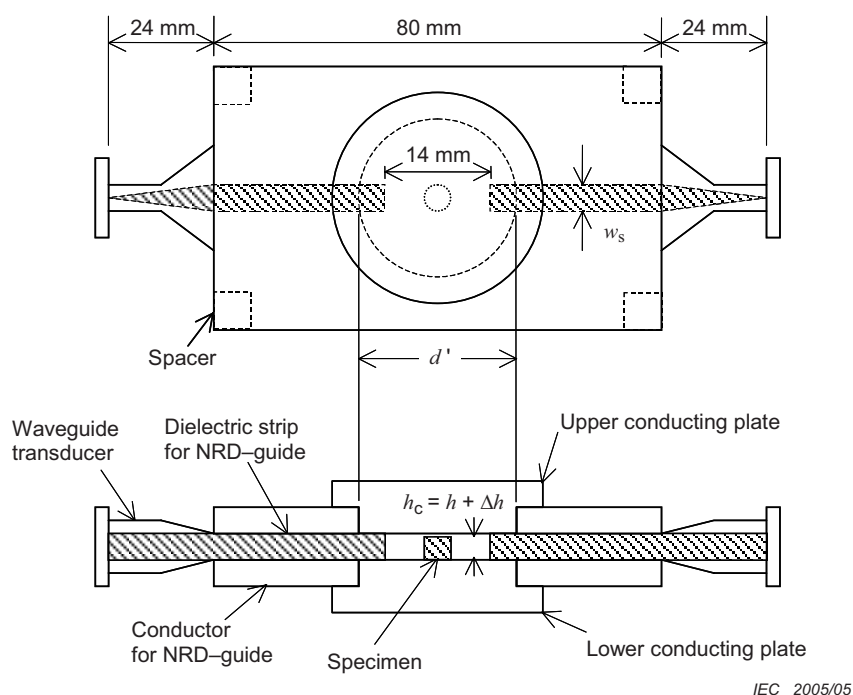
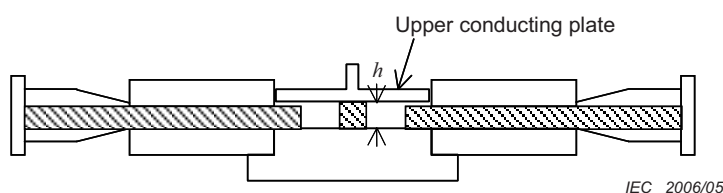
Figure 2b – Apparatus for ε' and $\tan \delta$ measurementFigure 2c – Apparatus for TCF and $TC\varepsilon$ measurement

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

Figure 2c shows an apparatus for measuring the temperature coefficient of resonance frequency TCF or that of relative permittivity $TC\varepsilon$. For this measurement, the upper conducting plate should be contacted to the dielectric specimen. The height h_s of dielectric strip for NRD-guide is designed to be smaller than height h of the dielectric specimen. The upper conducting plate is set gently to touch the top face of the specimen, so that an excessive pressure does not damage the surface of conducting plate.

As shown in Table 1, a diameter of the conducting plates in Figure 2b is determined by the diameter of dielectric specimen. In this measurement method, the ε' and $\tan \delta$ are calculated under the condition that the conducting plates have an infinitely large diameter. As actual conducting plates have a finite diameter, a part of electro-magnetic energy leaks outward the conducting plates. Although this leaky energy shifts the resonance frequency and decreases the unloaded Q , its contribution is negligibly small under the condition of $d'/d > 5$.

Table 2 shows the example of dimensions for dielectric strips of NRD-guide in Figure 2b. Dielectric strips of the NRD-guide are made of PTFE or cross-linked styrene copolymer.

Figure 3 shows a waveguide transducer that connects the measuring apparatus to the measurement equipment with WR-15 or WR-10 waveguides. Table 3 shows the dimensions of the waveguide transducers. As shown in Figure 2b, the end of the dielectric strip of the NRD-guide is sharpened in the transducer.

Table 1 – Diameter of conducting plate

Diameter d'	$d' = 5d \sim 10d$ d : diameter of dielectric specimen
Material of conducting plate	Copper or silver is recommended

Table 2 – Dimension of dielectric strip of NRD-guide

Material	Measurement frequency range GHz	Height h_s mm	Width w_s mm
PTFE ($\varepsilon' = 2,0$)	55 to 65	2,25	2,50
	75 to 80	1,80	1,90
Cross-linked styrene Copolymer ($\varepsilon' = 2,5$)	55 to 65	2,25	2,00
	75 to 80	1,80	1,60

Table 3 – Dimensions of waveguide transducer

Waveguide	Frequency range GHz	h_{wg} mm	w_{wg} mm	h_s mm
WR-15	55 to 65	3,80	1,90	2,25
WR-10	75 to 80	2,54	1,27	1,80