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Waveguide type dielectric resonators –

Part 1: Generic specification

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

WAVEGUIDE TYPE DIELECTRIC RESONATORS –

Part 1: Generic specification

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

IEC 61338-1 cancels and replaces the first edition of IEC 61338-1-1 published in 1996 and the first edition of IEC 61338-1-2 published in 1998.

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

FDIS	Report on voting
49/690/FDIS	49/699/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 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: Generic specification

1 General

1.1 Scope

This part of IEC 61338 applies to waveguide type dielectric resonators of assessed quality using either capability approval or qualification approval procedures. It also lists the test and measurement procedures which may be selected for use in detail specifications for such resonators.

1.2 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 60027 (all parts), *Letter symbols to be used in electrical technology*

IEC 60050(561):1991, *International Electrotechnical Vocabulary (IEV) – Chapter 561: Piezo-electric devices for frequency control and selection*

IEC 60068-1:1988, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-1:1990, *Environmental testing – Part 2: Tests – Tests A: Cold*

IEC 60068-2-2:1974, *Environmental testing – Part 2: Tests – Tests B: Dry Heat*

IEC 60068-2-6:1995, *Environmental testing – Part 2: Tests – Tests Fc: Vibration (sinusoidal)*

IEC 60068-2-7:1983, *Environmental testing – Part 2: Tests – Tests Ga and guidance: Acceleration, steady state*

IEC 60068-2-13:1983, *Environmental testing – Part 2: Tests – Tests M: Low air pressure*

IEC 60068-2-14:1984, *Environmental testing – Part 2: Tests – Tests N: Change of temperature*

IEC 60068-2-20:1979, *Environmental testing – Part 2: Tests – Tests T: Soldering*

IEC 60068-2-21:1999, *Environmental testing – Part 2: Tests – Tests U: Robustness of terminations and integral mounting devices*

IEC 60068-2-27:1987, *Environmental testing – Part 2: Tests – Tests Ea and guidance: Shock*

IEC 60068-2-29:1987, *Environmental testing – Part 2: Tests – Tests Eb and guidance: Bump*

IEC 60068-2-30:1980, *Environmental testing – Part 2: Tests – Tests Db and guidance: Damp heat, cyclic (12 +12 hour cycle)*

IEC 60068-2-58:2004, *Environmental testing – Part 2-58: Tests – Test Td: Test methods for solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD)*

IEC 60068-2-78, *Environmental testing – Part 2: Tests – Test Cab: Damp heat, steady state*

IEC 60617, *Graphical symbols for diagrams*

IEC 61338-1-3:1999, *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*

IEC 61338-4, *Waveguide type dielectric resonators of assessed quality – Part 4: Sectional specification* [1]

ISO 1000:1992, *SI units and recommendation for the use of their multiples and of certain other units*

QC 001001:2000, *IEC Quality Assessment System for Electronic Components (IECQ) – Basic Rules*

QC 001002-1:1998, *IEC Quality Assessment System for Electronic Components (IECQ) – Rules of Procedure – Part 1: Administration*

QC 001002-2:1998, *IEC Quality Assessment System for Electronic Components (IECQ) – Rules of Procedure – Part 2: Documentation*

QC 001002-3:1998, *IEC Quality Assessment System for Electronic Components (IECQ) – Rules of Procedure – Part 3: Approval Procedures*

QC 001005:2000, *Register of Firms, Products and Services approved under the IECQ System, including ISO 9000*

1.3 Order of precedence

Where any discrepancies occur for any reason, documents shall rank in the following order of priority:

– detail specification;
– sectional specification;
– generic specification;
– any other international documents (for example, of the IEC) to which reference is made.

The same order of preference shall apply to equivalent national documents.

2 Terminology and general requirements

2.1 General

Units, graphical symbols, letter symbols and terminology shall whenever possible, be taken from the following documents:

ISO 1000	SI units and recommendations for the use of their multiples and of certain other units
IEC 60617	Graphical symbols for diagrams
IEC 60027	Letter symbols to be used in electrical technology
IEC 60050	International Electrotechnical Vocabulary

[1] To be published.

Any other units, symbols and terminology peculiar to one of the components covered by this generic specification, shall be taken from the relevant IEC or ISO documents listed under 1.2, Normative references.

The following paragraphs contain additional terminology applicable to waveguide type dielectric resonators.

2.2 Definitions

The following paragraphs contain additional terminology applicable to waveguide type dielectric resonators.

2.2.1 Dielectric material

Material which predominantly exhibits dielectric properties.

NOTE The dielectric material defined herein is intended to be used for resonator applications at high frequency. i.e. UHF or SHF range. Therefore, the dielectric material is required to have high dielectric constant, a low loss factor and a low temperature coefficient of permittivity.

2.2.2 Electric constant (ε_0)

Constant equal to 8,8542 × 10^{-12} As V^{-1} m^{-1}, defined by the permittivity of vacuum.

2.2.3 Relative permittivity (ε_r)

Absolute permittivity of a material or medium divided by the electric constant ε_0.

NOTE The complex relative permittivity ε_r is defined as

$$\varepsilon_r = \varepsilon' - j\varepsilon'', \ \varepsilon' = \mathrm{Re}\ (\varepsilon), \ \varepsilon'' = -\ \mathrm{Im}\ (\varepsilon)$$

where

ε' is usually called dielectric constant;

ε'' corresponds to the dielectric loss of the material.

2.2.4 Absolute permittivity (ε)

Quantity which when multiplied by the electric field strength E is equal to the electric flux density D.

$$D = \varepsilon E, \ \varepsilon = \varepsilon_0\ \varepsilon_r$$

2.2.5 Loss angle (δ)

Phase displacement between the component of the electric flux density and the electric field strength.

2.2.6 Loss factor

Tangent of the loss angle δ.

$$\tan \delta = \varepsilon''/\varepsilon'$$

NOTE The loss factor can be determined by the ratio of the magnitude of the negative part to the real part of the complex relative permittivity.

2.2.7 Quality factor of a material (Q_o)

Reciprocal of the tangent of the loss angle,

$$Q_o = \varepsilon'/\varepsilon'' = 1/\tan\delta$$

NOTE The quality factor of a material is also defined as 2π times the ratio of the stored electromagnetic energy to the energy dissipated in the material per cycle. It is frequency dependent.

2.2.8 Temperature coefficient of permittivity ($TC\varepsilon$)

Fractional change of permittivity due to a change in temperature divided by the change in temperature.

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

where

ε_T is the permittivity at temperature T;

ε_{ref} is the permittivity at reference T_{ref}.

2.2.9 Coefficient of linear thermal expansion (α)

Fractional change of dimension due to a change in temperature divided by the change in temperature.

$$\alpha = \frac{\ell_T - \ell_{ref}}{\ell_{ref}(T - T_{ref})} \times 10^6 \qquad \left(1 \times 10^{-6}\ /K\right)$$

where

ℓ_T is the dimension at temperature T;

ℓ_{ref} is the dimension at reference temperature T_{ref}.

2.2.10 Dielectric resonator

Resonator using dielectrics with a high dielectric constant and the structure of which is a dielectric waveguide of finite length.

NOTE The dielectric resonators in use are always shielded with conductors.

2.2.11 Dielectric support

Element supporting a dielectric resonator. The support is generally used for $TE_{01\delta}$ mode resonators and has a low dielectric constant (see Figure 1).

2.2.12 TE mode dielectric resonator

Dielectric resonator characterized by a transverse electric mode (TE mode) field distribution and usually having a high unloaded quality factor Q_u.

2.2.13 $TE_{01\delta}$ mode dielectric resonator

Dielectric resonator characterized by a dominant TE mode field distribution, whose field leaks in the direction of wave propagation (see Figure 1).

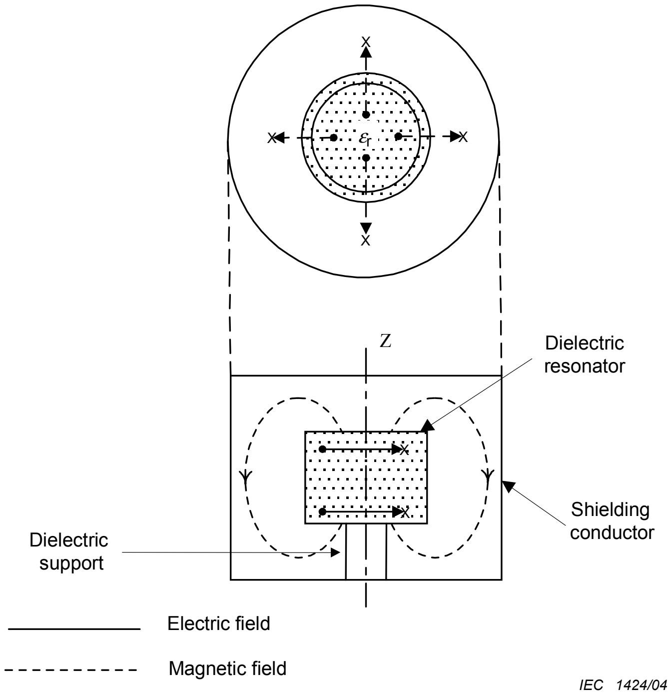

Figure 1 – $TE_{01\delta}$ mode dielectric resonator

2.2.14 TM mode dielectric resonator

Dielectric resonator characterized by a transverse magnetic mode (TM mode) field distribution (see Figure 2).

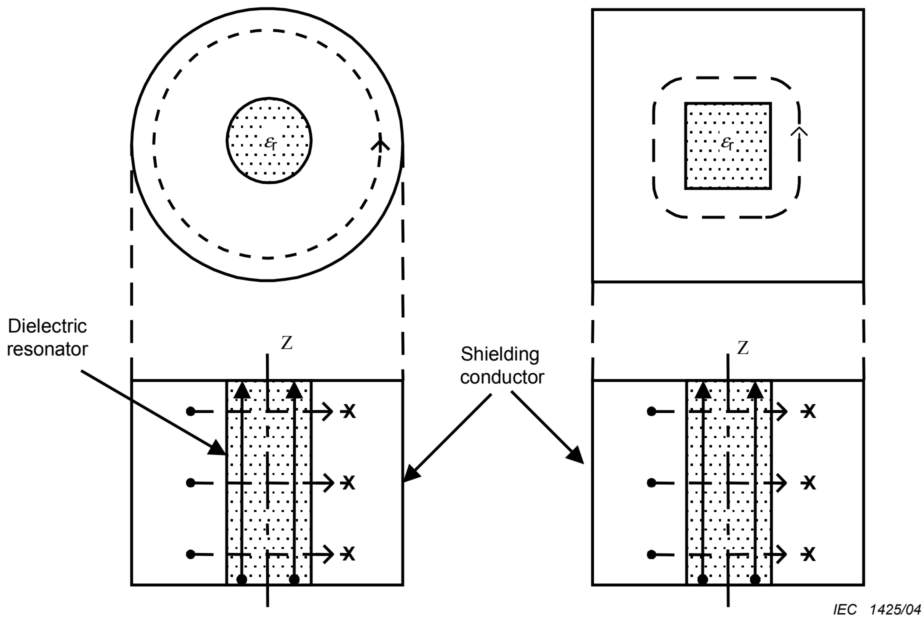

Figure 2 – TM mode dielectric resonator

2.2.15 TM$_{01\delta}$ mode dielectric resonator

Dielectric resonator characterized by a dominant TM mode field distribution, whose field leaks in the direction of wave propagation (see Figure 3).

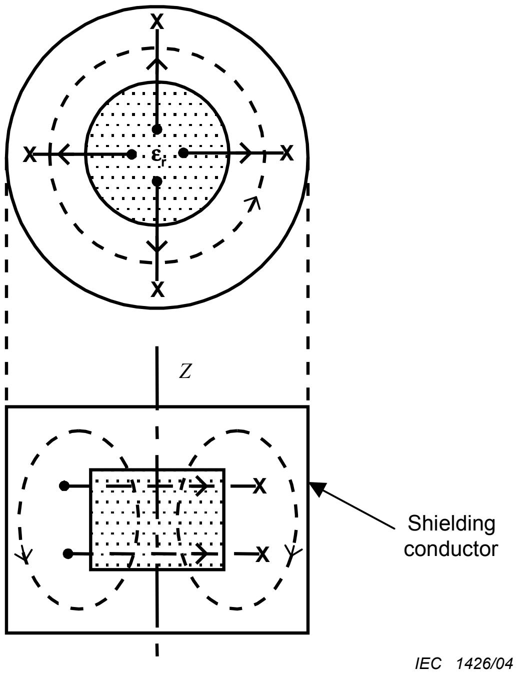

Figure 3 – TM$_{01\delta}$ mode dielectric resonator

2.2.16 Hybrid mode dielectric resonator

Dielectric resonator characterized by a hybrid mode field distribution. Hybrid mode is the mode which has axial components both of the electric and magnetic fields (see Figure 4).

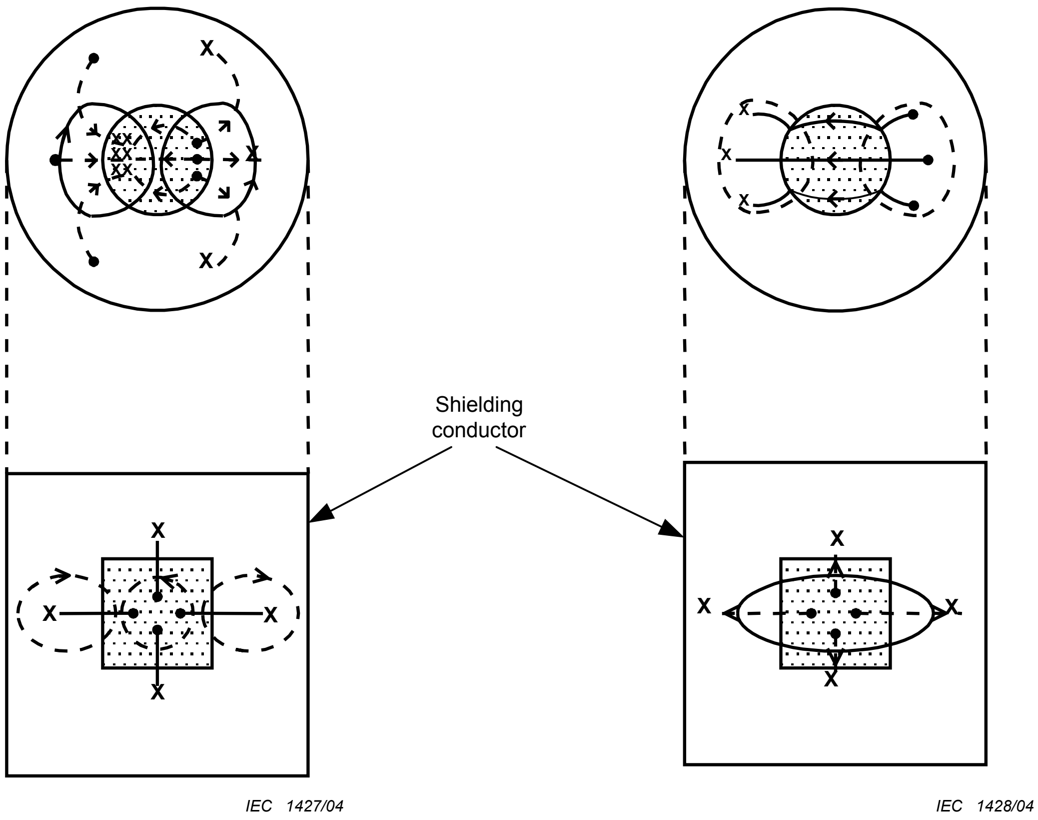

Figure 4a – **$EH_{11\delta}$ mode**

Figure 4b – **$HE_{11\delta}$ mode**

Figure 4 – Hybrid mode dielectric resonator

2.2.17 Multimode dielectric resonator

Dielectric resonator characterized by the existence of several orthogonal resonance modes, the resonance frequencies of which coincide in such a way that any of which cannot be obtained by the superposition of others (see Figure 5). Any electromagnetic field perturbation affects independence of certain of these modes and causes energy coupling between them. This allows realization of reduced volume filters.

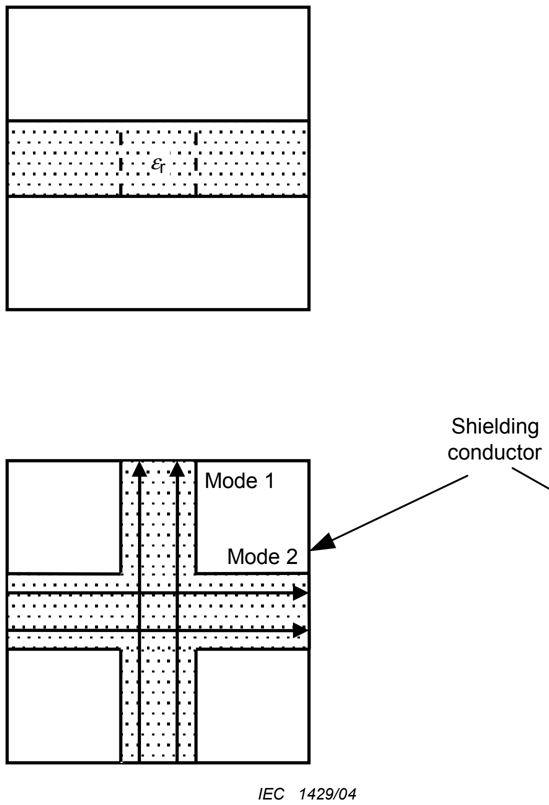

Figure 5a – $TM_{11\delta}$ dual mode

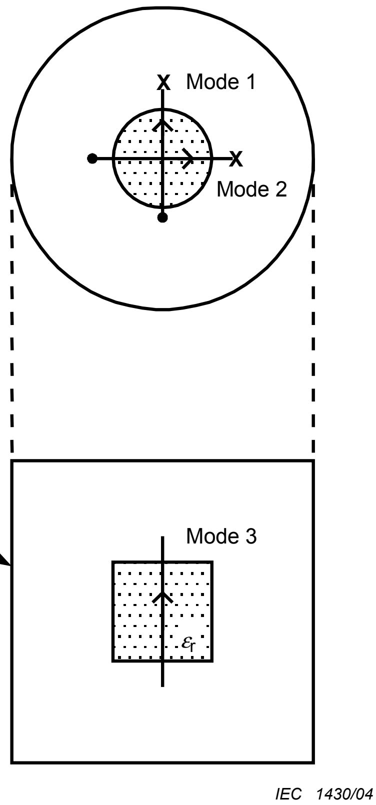

Figure 5b – Triple mode of $EH_{11\delta}$ dual mode and $TM_{11\delta}$ mode

Figure 5 – Multimode dielectric resonators

2.2.18 TEM mode dielectric resonator

Dielectric resonator characterized by a transverse electromagnetic mode (TEM mode) field distribution causing significant size reduction effect (see Figure 6).

2.2.19 Coaxial dielectric resonator

Dielectric resonator characterized by a TEM mode field distribution with a coaxial waveguide structure of finite length (see Figure 6).

2.2.20 Quarter wavelength resonator

Resonator characterized by any guided mode field distribution with standing wave of a quarter wavelength (see Figure 6a in the case of TEM mode).

2.2.21 Half wavelength resonator

Resonator characterized by any guided mode field distribution with standing wave of a half wavelength (see Figure 6b in the case of TEM mode).

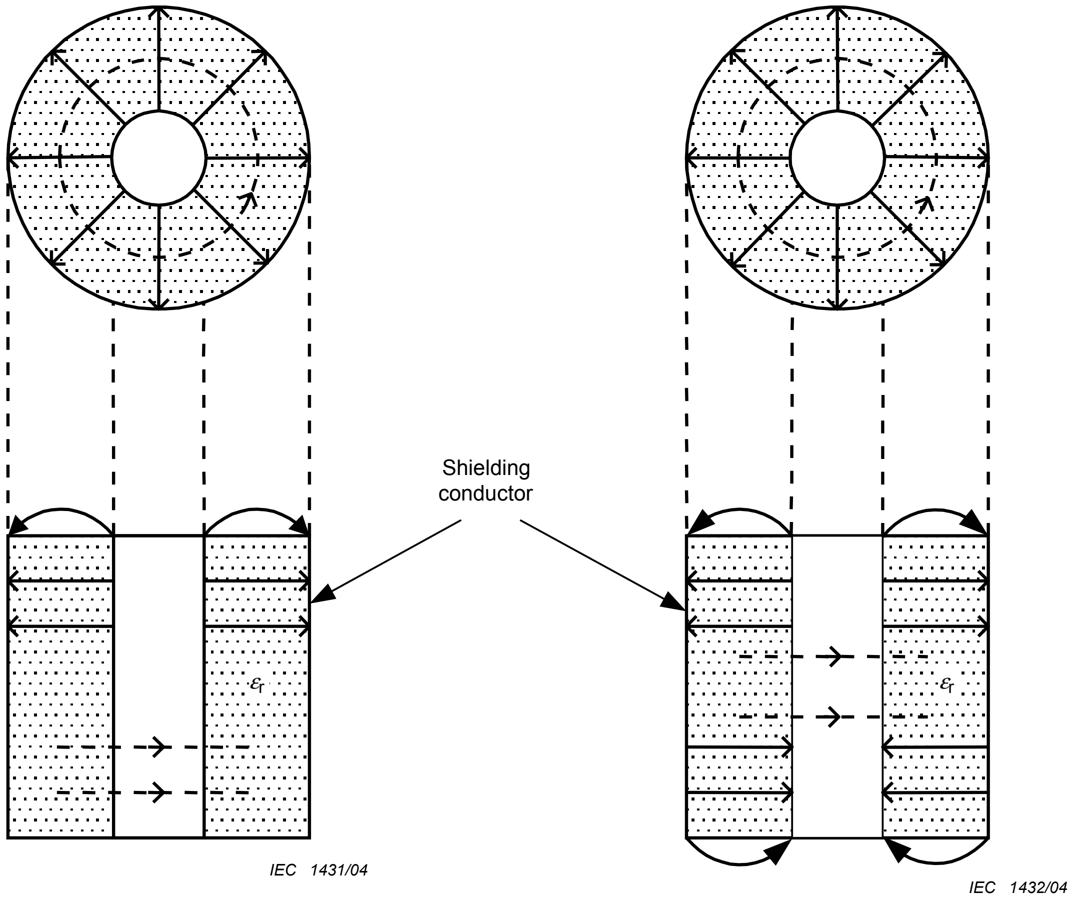

Figure 6a – Quarter wavelength TEM mode

Figure 6b – Half wavelength TEM mode

Figure 6 – TEM mode coaxial dielectric resonator

2.2.22 Stripline resonator

Dielectric resonator characterized by a TEM mode field distribution. The structure is a stripline waveguide of finite length (see Figure 7).

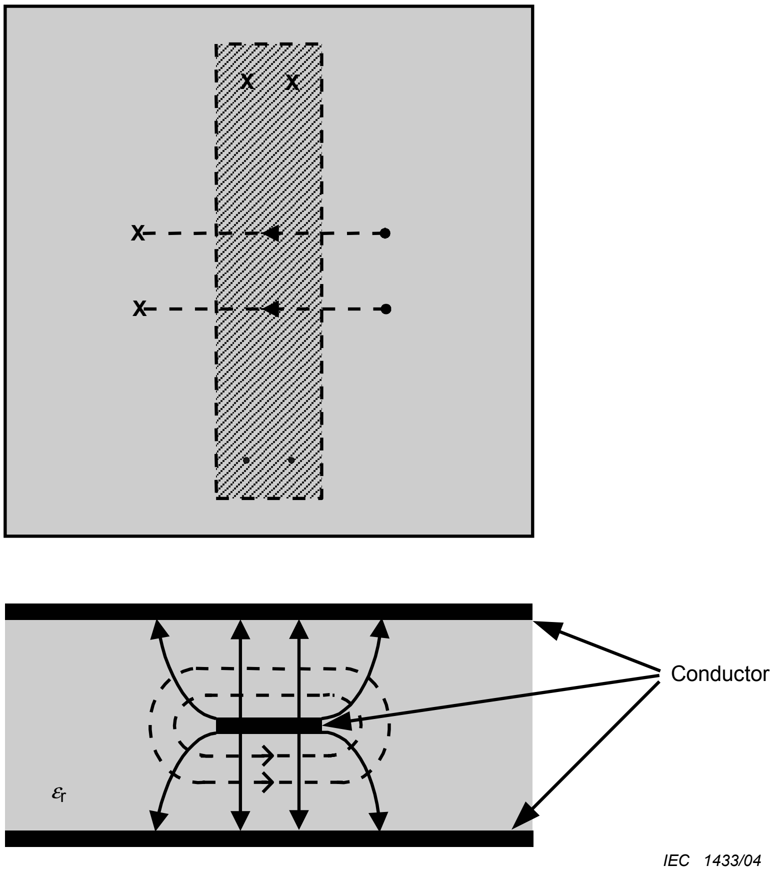

Figure 7 – Half wavelength stripline resonator

2.2.23 Microstripline resonator

Dielectric resonator characterized by a TEM mode field distribution. The structure is a microstripline waveguide of finite length (see Figure 8).

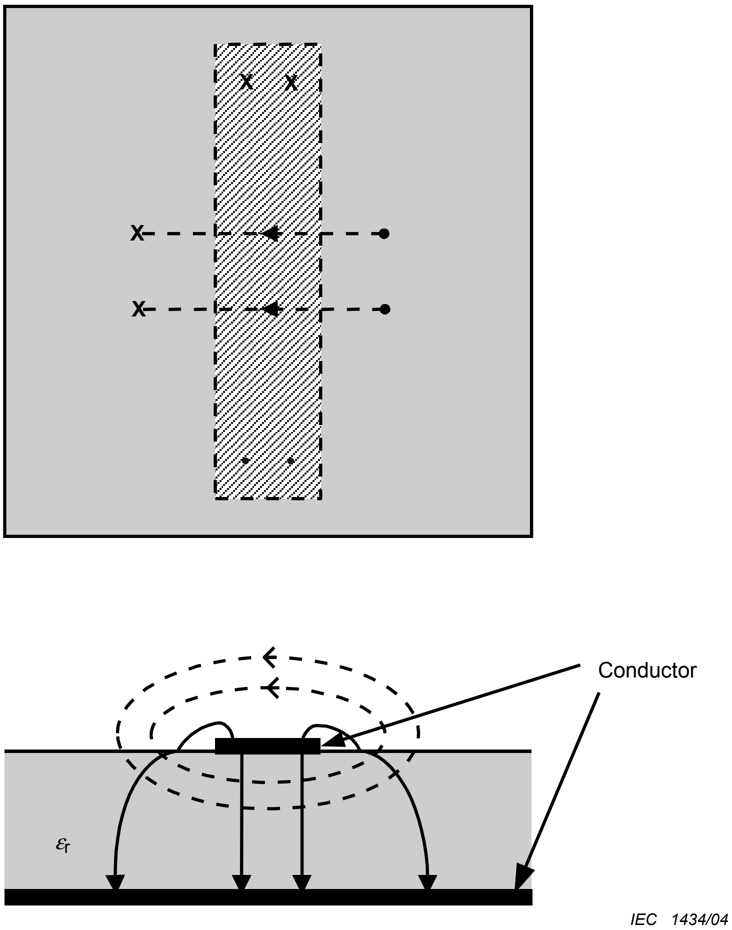

Figure 8 – Half wavelength microstripline resonator

2.2.24 Coplanar resonator

Dielectric resonator characterized by a TEM mode field distribution. The structure is a coplanar-line waveguide of finite length (see Figure 9).

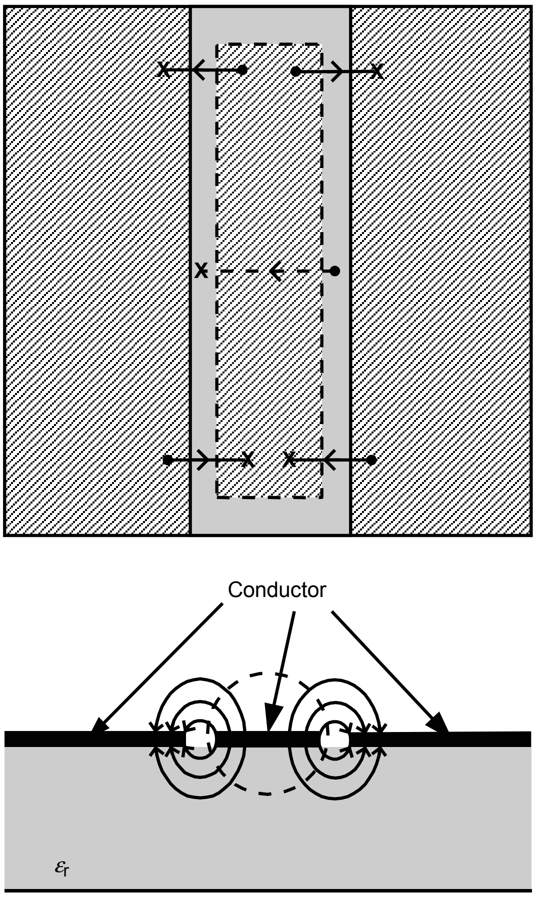

Figure 9 – Coplanar resonator

2.2.25 Quality factor (Q)

The value defined as 2π times the ratio of the stored electromagnetic energy to the energy dissipated per cycle.

$$Q = 2\pi \frac{\textit{Electromagnetic energy stored in the resonator}}{\textit{Energy dissipated per cycle}}$$

2.2.26 Unloaded quality factor (Q_u)

Quality factor for the dielectric resonator with support and shielding conductors, excluding the energy dissipated in the external circuits.

$$\frac{1}{Q_u} = \frac{1}{Q_d} + \frac{1}{Q_s} + \frac{1}{Q_c} + \frac{1}{Q_r}$$

where

Q_d is the quality factor due to the dielectric loss of the dielectric material;

Q_s is the quality factor due to the dielectric loss of the support;

Q_c is the quality factor due to the dielectric loss of the shielding conductors;

Q_r is the quality factor due to the radiation loss.

2.2.27 External quality factor (Q_e)

Quality factor due to the energy loss in the external circuit, excluding the energy dissipated in the resonator.

2.2.28 Loaded quality factor (Q_L)

Actual quality factor for the entire circuit, including all energy losses both in the resonator and in the external circuit.

$$\frac{1}{Q_L} = \frac{1}{Q_u} + \frac{1}{Q_e}$$

2.2.29 Resonance frequency

Frequency at which the average electric energy stored in the resonator is equal to the average magnetic energy stored in the resonator.

2.2.30 Temperature coefficient of resonance frequency (TCF)

The fractional change in frequency divided by the change in temperature.

$$TCF = \frac{f_T - f_{ref}}{f_{ref}\left(T - T_{ref}\right)}$$

where

f_T is the resonance frequency at temperature T;

f_{ref} is the frequency at reference temperature T_{ref}.

2.3 Preferred values for ratings and characteristics

Values should preferably to chosen from the following paragraphs.

2.3.1 Climatic category

40/085/56

For requirements where the operating temperature range of the resonator is greater than –40 °C to +85 °C a climatic category consistent with the operating temperature range shall be specified.

2.3.2 Bump severity

4000 ± 10 bumps at 390 m/s^2 peak acceleration in each direction along three mutually-perpendicular axes. Pulse duration 6 ms.

2.3.3 Vibration severity

10 Hz to 60 Hz 0,75 mm displacement amplitude (peak value 60 Hz to 2000 Hz 98,1 m/s^2 acceleration amplitude (peak value)	10 sweep cycles (10 Hz to 2000 Hz to 10 Hz) in each of three mutually-perpendicular axes at 1 octave/min

2.3.4 Shock severity

981 m/s^2 peak acceleration for 6 ms duration; three shocks in each direction along three mutually-perpendicular axes; half sine pulse.

2.4 Marking

Each resonator shall be indelibly and legibly marked with

– nominal frequency (which may be in code form);
– mark of origin (manufacturer's name, which may be in code form, or trade mark);
– date code;
– any other information necessary to provide a complete definition of the resonator.

NOTE For microminiature enclosures, the marking may be replaced by an alternative marking system, to avoid the deterioration of electrical performance. The marking should be made on the transport package.

3 Quality assessment procedures

3.1 General

Two methods are available for the approval of waveguide type dielectric resonators of assessed quality. They are qualification approval and capability approval.

3.2 Primary stage of manufacture

The primary stage of manufacture for a waveguide type dielectric resonator in accordance with Clause 4 of QC 001002-3 is the powder mix.

3.3 Structurally similar components

The grouping of structurally similar waveguide type dielectric resonators for the purpose of qualification approval, capability approval and quality conformance inspection shall be prescribed in the relevant sectional specification.

3.4 Sub-contracting

These procedures shall be in accordance with Clause 3 of QC 001002-3.

3.5 Manufacturer's approval

To obtain the manufacturer's approval, the manufacturer shall meet the requirements of Clause 2 of QC 001002-3.

3.6 Approval procedures

3.6.1 General

To qualify a waveguide type dielectric resonator, either capability approval or qualification approval procedures may be used. These procedures conform to those stated in QC 001001 and QC 001002-3.

3.6.2 Capability approval

Capability approval is appropriate when structurally similar waveguide type dielectric resonators, based on common design rules, are fabricated by a group of common processes.

Under capability approval, detail specifications fall into the following three categories.

3.6.2.1 Capability Qualifying Components (CQCs)

A detail specification shall be prepared for each CQC as agreed with the National Supervising Inspectorate (NSI). It shall identify the purpose of the CQC and include all relevant stress levels and test limits.

3.6.2.2 Standard catalogue items

When a component covered by the capability approval procedure is intended to be offered as a standard catalogue item, a detail specification complying with the blank detail specification shall be written. Such specifications shall be registered by the IECQ and the component may be listed in QC 001005.

3.6.2.3 Custom built waveguide type dielectric resonators

The content of the detail specification shall be by agreement between the manufacturer and the customer in accordance with 11.7.4.2 of QC 001002-2.

Further information on detail specifications is contained in the sectional specification IEC 61338-4.

The product and capability qualifying components (CQCs) are tested in combination and approval given to a manufacturing facility on the basis of validated design rules, processes and quality control procedures.

Further information is given in 3.7 and in the sectional specification IEC 61338-4.

3.6.3 Qualification approval

Qualification approval is appropriate for components manufactured to a standard design and established production process and conforming to a published detail specification.

The programme of tests defined in the detail specification for the appropriate assessment and severity level applies directly to the waveguide type dielectric resonator to be qualified, as prescribed in 3.8 and the sectional specification IEC 61338-4.

3.7 Procedures for capability approval

3.7.1 General

The procedures for capability approval shall be in accordance with QC 001002-3.

3.7.2 Eligibility for capability approval

The manufacturer shall comply with the requirements of Clause 4 of QC 001002-3 and the primary stage of manufacture as defined in 3.1 of this generic specification.

3.7.3 Application for capability approval

In order to obtain capability approval the manufacturer shall apply the rules of procedure given in Clause 4 of QC 001002-3.

3.7.4 Granting of capability approval

Capability approval shall be granted when the procedures in accordance with Clause 4 of QC 001002-3 have been successfully completed.

3.7.5 Description of capability

The contents of the description of capability shall be in accordance with the requirements of the sectional specification.

The NSI shall treat the description of capability as a confidential document. The manufacturer may, if he so wishes, disclose part or all of it to a third party.

3.8 Procedures for qualification approval

3.8.1 General

The procedures for qualification approval shall be in accordance with Clause 3 of QC 001002-3.

3.8.2 Eligibility for qualification approval

The manufacturer shall comply with the requirements of Clause 3 of QC 001002-3 and the primary stage of manufacture as defined in 3.1 of this generic specification.

3.8.3 Application for qualification approval

In order to obtain qualification approval the manufacturer shall apply the rules of procedure given in Clause 3 of QC 001002-3.

3.8.4 Granting of qualification approval

Qualification approval shall be granted when the procedures in accordance with Clause 3 of QC 001002-3 have been successfully completed.

3.8.5 Quality conformance inspection

The blank detail specification associated with the sectional specification shall prescribe the test schedule for quality conformance inspection.

3.9 Test procedures

The test procedures to be used shall be selected from this generic specification. If any required test is not included in this generic specification, then it shall be defined in the detail specification.

3.10 Screening requirements

Where screening is required by the customer for waveguide type dielectric resonators, this shall be specified in the detail specification.

3.11 Rework and repair work

3.11.1 Rework

Rework is the rectification of processing errors and shall not be carried out if prohibited by the sectional specification. The sectional specification shall state if there is a restriction on the number of occasions that rework may take place on a specific component.

All rework shall be carried out prior to the formation of the inspection lot offered for inspection to the requirements of the detail specification.

Such rework procedures shall be fully described in the relevant documentation produced by the manufacturer and shall be carried out under the direct control of the chief inspector. Subcontracting of rework is not permitted.

3.11.2 Repair work

Repair work is the correction of defects in a component after release to the customer.

Components that have been repaired can no longer be considered as representative of the manufacturer's production and may not be released under the IECQ system.

3.12 Certified records of released lots

When certified records of released lots (CRRL) are prescribed in the sectional specification for qualification approval and are requested by the customer the results of the specified tests shall be summarised (see Clause 14 of QC 001002-2).

3.13 Validity of release

Waveguide type dielectric resonators held for a period exceeding two years following acceptance inspection shall be re-inspected for the electrical tests detailed in 4.5.2 and 4.5.3, with a sample tested as described in 4.5.4 prior to release.

3.14 Release for delivery

Waveguide type dielectric resonators shall be released in accordance with Clauses 3 and 4 of QC 001002-3.

3.15 Unchecked parameters

Only those parameters of a component which have been specified in a detail specification and which were subject to testing can be assumed to be within the specified limits. It should not be assumed that any parameter not specified will remain unchanged from one component to another. Should it be necessary for further parameters to be controlled, then a new, more extensive, detail specification should be used. The additional test method(s) shall be fully described and appropriate limits, quality and inspection levels specified.

4 Test and measurement procedures

4.1 General

The test and measurement procedures shall be carried out in accordance with the relevant detail specification.

4.2 Test and measurement conditions

4.2.1 Standard conditions for testing

Unless otherwise specified all tests shall be carried out under standard atmospheric conditions for testing as specified in 5.3 of IEC 60068-1.

Temperature	15 °C to 35 °C
Relative Humidity	25 % to 75 %
Air pressure	86 kPa to 106 kPa

In case of dispute, the reference conditions are:

Temperature	(23 ± 1) °C
Relative Humidity	48 % to 52 %
Air pressure	86 kPa to 106 kPa

Before measurements are made, the resonator shall be stored at the measuring temperature for a time sufficient to allow the resonator to reach thermal equilibrium. Controlled recovery conditions and standard conditions for assisted drying are given in 5.4 of IEC 60068-1.

When measurements are made at a temperature other then the standard temperature, the results shall, where necessary, be corrected to the specified temperature. The ambient temperature during measurements shall be recorded and stated in the test report.

4.2.2 Precision of measurement

The limits given in detail specifications are true values. Measurement inaccuracies shall be taken into account when evaluating the results. Precautions shall be taken to reduce measurement errors to a minimum.

4.2.3 Alternative test methods

Measurements shall preferably be carried out using the methods specified. Any other method giving equivalent results may be used except in case of dispute.

NOTE By "equivalent" is meant that the value of the characteristic established by such other method falls within the specified limits when measured by the specified method.

4.3 Visual inspection

Unless otherwise specified the visual examination shall be performed under normal factory lighting and visual conditions.

The resonator shall be visually examined to ensure that the condition, workmanship and finish are satisfactory. The marking shall be legible.

4.4 Dimension and gauging procedure

The dimensions shall be measured and shall comply with the specified values.

4.5 Electrical test procedures

4.5.1 General

The resonator measurement is made to determine, (1) the transmission characteristics of dielectric resonators; resonance frequency f_0, unloaded quality factor Q_u and temperature coefficient of resonance frequency TCF, and (2) the dielectric characteristics of dielectric resonators, relative permittivity ε', loss factor tan δ and TCF.

The electrical properties can be tested with conventional measurement methods for the transmission characteristics of $TE_{01\delta}$ or TEM mode resonators and of $TE_{01\delta}$ mode reaction type resonator for the usage as dielectric oscillators. The reflection measurement method is also available, but is not preferred due to its larger measurement error.

NOTE A new measurement method for the dielectric properties, which is based on a transmission measurement of TE_{011} mode resonance, is proposed by IEC 61338-1-3.

Dielectric resonators are distinguished from the other resonators such as quartz crystal, ceramic or SAW resonators, because they are dealt in without metal case or connectors.

As the electrical properties of the $TE_{01\delta}$ and TEM mode resonators are dependent on their size of shielding conductors, the size of the test fixture and the insertion attenuation to be tested should be determined in advance between the supplier and purchaser.

4.5.2 Transmission characteristics of $TE_{01\delta}$ and TEM mode band-pass type resonators

4.5.2.1 Measurement circuit

Figure 10 shows the transmission measurement set-up with a network analyzer. The RF signal is fed from port 1 to port 2 through the resonator test fixture. All of these connections have to be made with RF coaxial cables, whose nominal impedance should be exactly equal to the system impedance.

NOTE A vector impedance meter or other resonator test equipment can be used instead of the network analyzer.

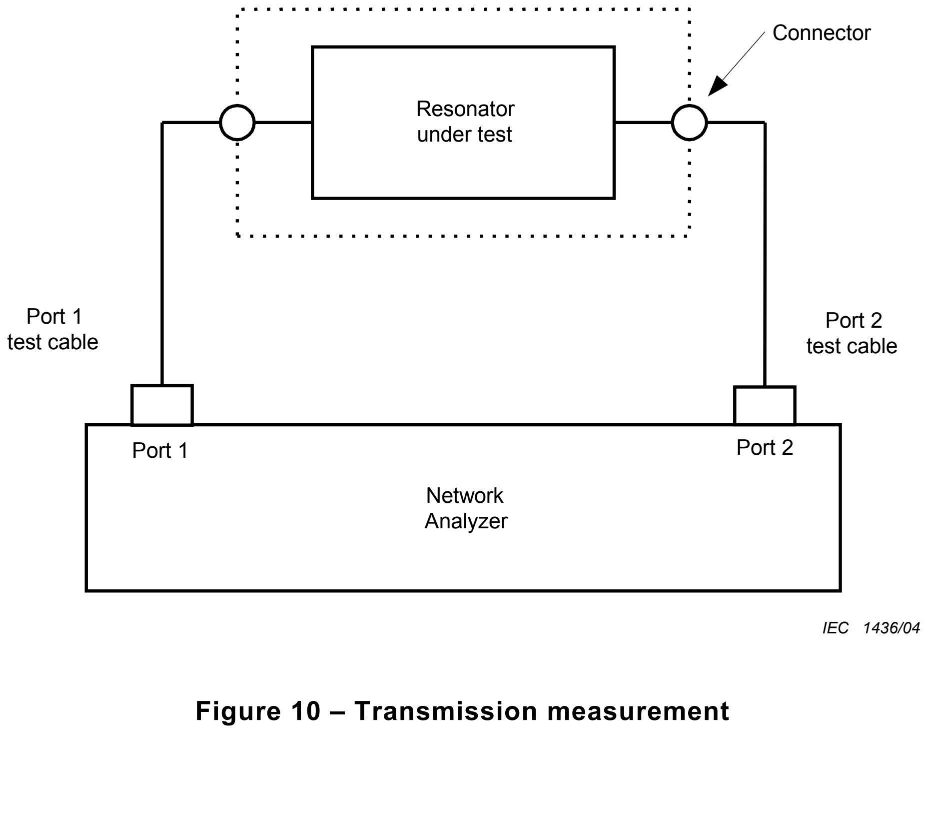

Figure 10 – Transmission measurement

4.5.2.2 Test fixture

Test fixtures A and B in Figure 11 are used for the transmission measurement of $TE_{01\delta}$ and TEM mode resonators, respectively. The distance between a dielectric resonator and coupling loop antenna, or coupling mono-pole antenna for TEM mode, at the top of semi-rigid cable is adjusted so that the minimum insertion attenuation should be around 30 dB to decrease the coupling loss.

For the $TE_{01\delta}$ mode resonator, the size of test fixtures, i.e. shielding conductors, should be determined in advance between supplier and purchaser. The material of test fixtures should be chosen from a high conductivity metal such as copper or silver as the unloaded quality factor is dependent on the conductivity.

4.5.2.3 Measurement method

Connect port 1 and port 2 directly by a coaxial cable and determine the reference level by calibration procedure of the network analyzer. Insert the test fixture with resonator. The attenuation relative to the reference level is the insertion attenuation.

4.5.2.4 Resonator electrical characteristics

An example of insertion attenuation is shown in Figure 12. The minimum insertion attenuation is the minimum value of the insertion attenuation in the vicinity of the nominal frequency.

The centre frequency f_c is the arithmetic mean of the two frequencies at which the attenuation relative to the minimum insertion attenuation reaches a specified value (e.g. 3 dB). The centre frequency is substituted for resonance frequency f_0.

The loaded quality factor Q_L is calculated by the following equation:

$$Q_L = \frac{f_0}{\Delta f}$$

where Δf is the difference between the two frequencies at which the attenuation relative to the minimum insertion attenuation reaches 3 dB.

The unloaded quality factor Q_u is calculated by the following equation:

$$Q_u = \frac{Q_L}{1 - 10^{-(IA_{min}/20)}}$$

where IA_{min} (dB) is the minimum insertion attenuation.

Temperature coefficient of resonance frequency TCF is given by the following equation:

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

where f_T and f_{ref} are the resonance frequencies at temperature T and reference temperature T_{ref} (T_{ref} = 20 °C to 25 °C).

It should be noticed that the TCF of $TE_{01\delta}$ mode resonator is dependent on ε' of test specimens, dimensions and coefficient of thermal expansion of test fixture, and *TCF* of dielectric support.

NOTE The effect of dimensions and thermal linear expansion coefficient of test fixtures and of *TCF* of dielectric support can be eliminated by measuring the TCF using the TE_{011} mode resonance (cf. 4.5.4).

Transmission characteristics of $TE_{01\delta}$ and TEM mode resonators are determined by f_0 , Q_u and TCF.

4.5.3 Transmission characteristics of $TE_{01\delta}$ mode band-stop type resonators

4.5.3.1 Measurement circuit

The circuit is shown in Figure 10.

4.5.3.2 Test fixture

Test fixture C in Figure 11 is used for the transmission measurement of $TE_{01\delta}$ mode band-stop type resonators. The insertion attenuation is determined by the distance between dielectric resonator and microstrip line. The insertion attenuation and the size of shielding conductor should be determined in advance between supplier and purchaser.

4.5.3.3 Measurement method

With the dielectric resonator removed from test fixture, measure the reference level in the vicinity of the nominal resonance frequency. Place the dielectric resonator to be tested exactly on the specified position in the fixture. The attenuation relative to the reference level is the insertion attenuation.

4.5.3.4 Resonator electrical characteristics

An example of insertion attenuation is shown in Figure 12 and Figure 13. Resonance frequency f_0 is the frequency at which the insertion attenuation reaches maximum. Insertion attenuation at this frequency is denoted as IA_{max} (dB). The loaded quality factor Q_L is given by the following equation:

$$Q_L = \frac{f_0}{f_4 - f_3}$$

where f_3 and f_4 are the frequencies at which the insertion attenuation IA (dB) is equal to

$$IA = 10 \log_{10} \frac{2}{1 + 10^{-(IA_{max}/10)}}$$

The unloaded quality factor Q_u is given by the following equation:

$$Q_u = \frac{f_0}{f_2 - f_1}$$

where f_1 and f_2 are the frequencies at which insertion attenuation IA (dB) is equal to

$$IA = IA_{max} - 10 \log_{10} \frac{2}{1 + 10^{-(IA_{max}/10)}}$$

4.5.4 Dielectric characteristics measurement

4.5.4.1 Measurement circuit

The circuit is shown in Figure 10.

4.5.4.2 Test fixture

Test fixture D in Figure 11 is used for the measurement of dielectric properties; ε', tan δ and TCF. The resonance frequency and unloaded Q of $TE_{01\delta}$ mode or TE_{011} mode resonance are also measured by using the fixture D. The dielectric properties are calculated from the measured f_0 and Q_u. Detailed description of the fixture is given in IEC 61338-1-3 .

4.5.4.3 Measurement method

Connect port 1 and port 2 in Figure 10 directly by a cable and determine the reference level by calibration procedure of the network analyzer. Insert the test fixture with dielectric specimen. The attenuation relative to the reference level is the insertion attenuation.

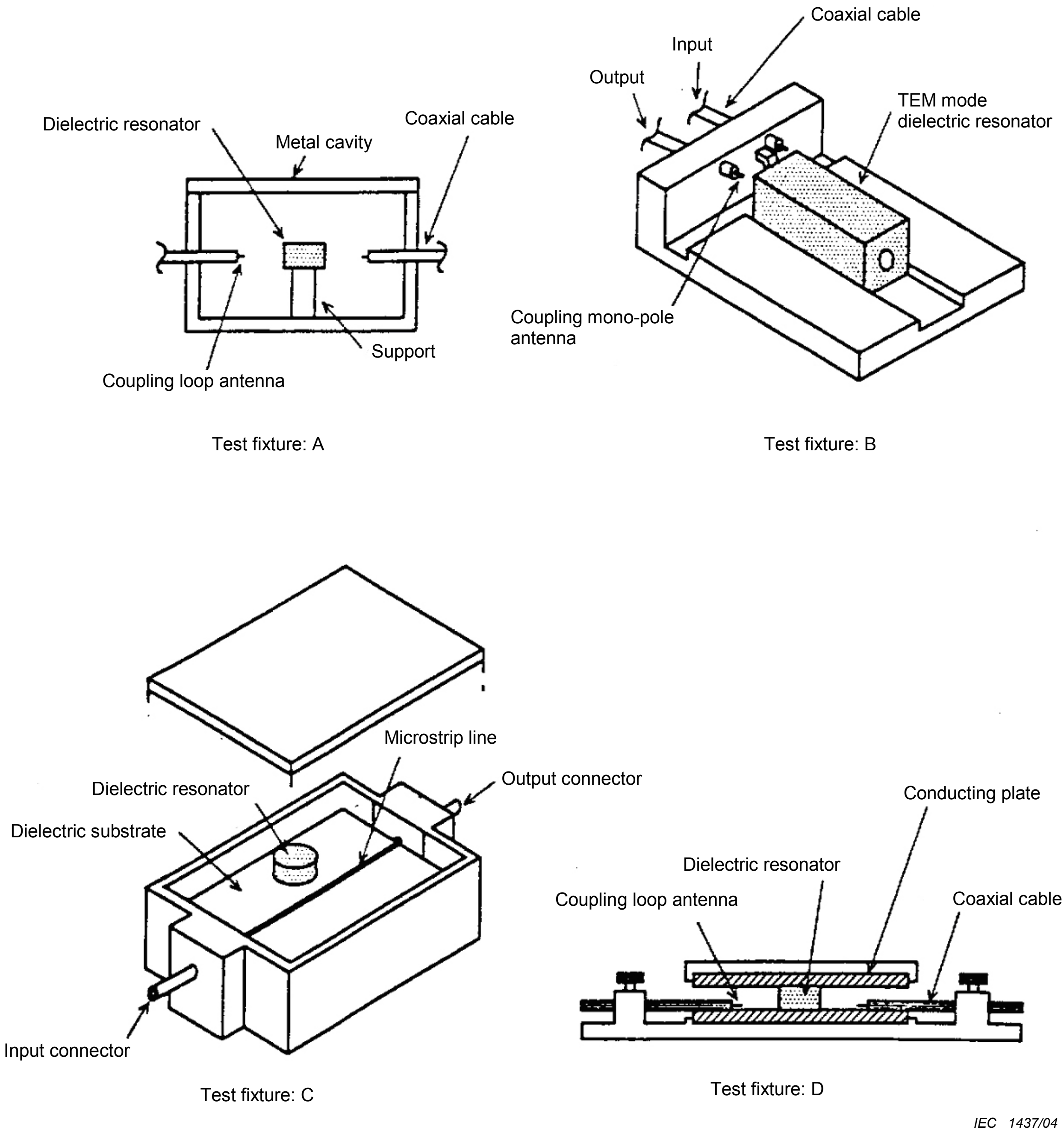

Figure 11 – Resonator test fixture

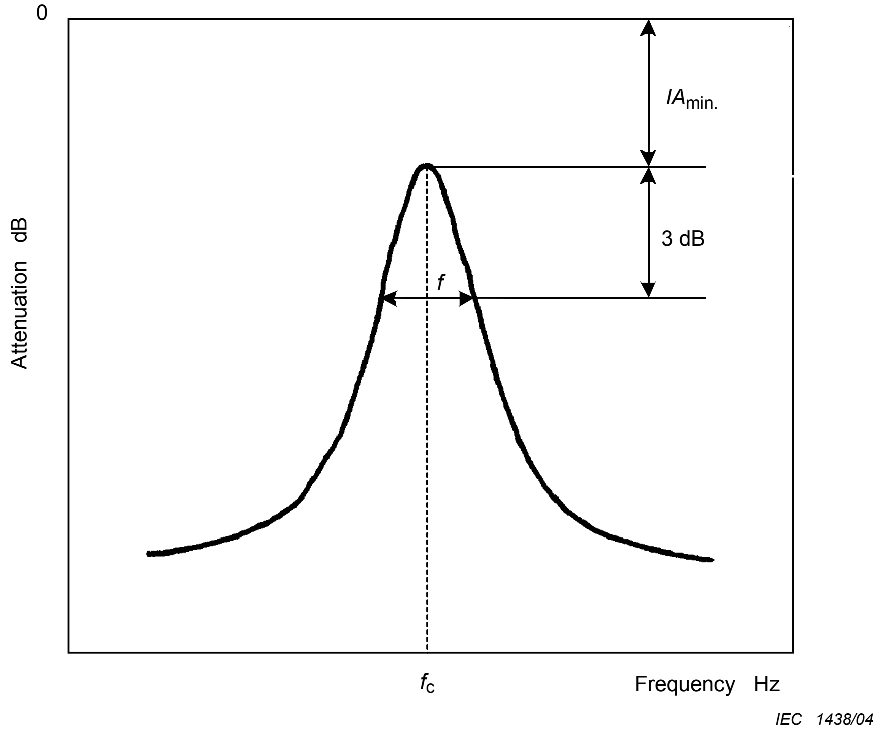

Figure 12 – Frequency response for test fixture A, B and D

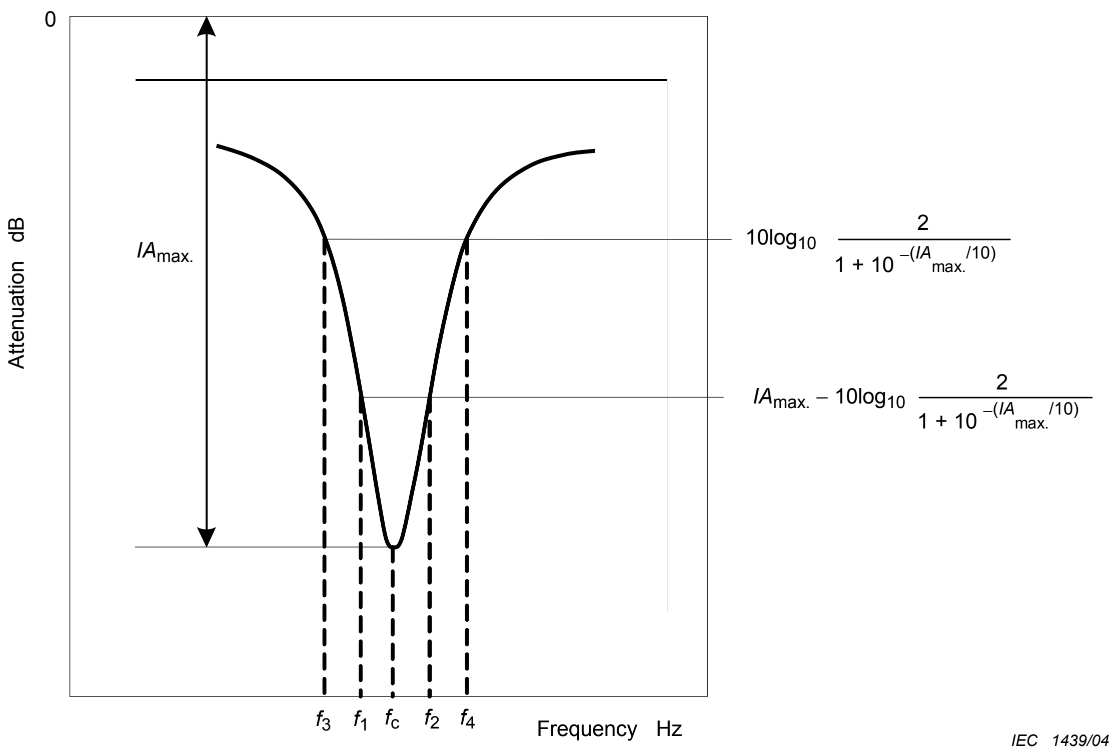

Figure 13 – Frequency response for test fixture C

4.5.4.4 Resonator electrical characteristics

Examples of frequency responses are shown in Figure 12 and Figure 13. The centre frequency f_c is the arithmetic mean of two frequencies at which the attenuation relative to the minimum insertion attenuation reaches a specified value (e.g. 3 dB). The centre frequency is substituted for resonance frequency f_0.

The loaded quality factor Q_L is calculated from the following equation:

$$Q_L = \frac{f_0}{\Delta f}$$

where Δf is the difference between the two frequencies at which the attenuation relative to the minimum insertion attenuation reaches 3 dB.

The unloaded quality factor Q_u is calculated from the following equation:

$$Q_u = \frac{Q_L}{1 - 10^{-(IA_{min}/20)}}$$

where IA_{min} (dB) is the minimum insertion attenuation which is adjusted to be around 30 dB.

The relative permittivity ε' and loss factor tan δ are calculated from f_0 and Q_u.

Detailed description of the calculation equations is given in draft IEC 61338-1-3.

Temperature coefficient of resonance frequency TCF is defined as the value which satisfies the following equation:

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

where $TC\varepsilon$ and α are the temperature coefficient of ε' and the coefficient of thermal expansion of the test specimen respectively.

The *TCF* is practically determined by the following equation:

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

where f_T and f_{ref} are the resonance frequencies at temperature T and reference temperature T_{ref} (T_{ref} = 20 °C to 25 °C).

When a non-linear dependence of resonance frequency on temperature is specified, the first and second order temperature coefficients of resonance frequency, TCF' and TCF'', are determined by the following equation:

$$\frac{f_T - f_{ref}}{f_{ref}} = TCF'(T - T_{ref}) + TCF''(T - T_{ref})^2$$

The TCF' and TCF'' are calculated from the resonance frequencies at three different temperatures T_{low}, T_{ref} and T_{high} in the operating temperature range.

NOTE The TCF measured by using the fixture D (TE_{011} mode resonance) approximately satisfies the equation $TCF = -½TC\varepsilon - \alpha$. While, the TCF measured by using the fixture A ($TE_{01\delta}$ mode resonance) does not usually satisfy this equation due to the difference of coefficients of thermal expansion between dielectric specimen and test fixture. A detailed description is given in IEC 61338-1-3.

4.6 Mechanical and environmental test procedures

4.6.1 Storage (non-destructive)

Unless otherwise specified in the detail specification the resonator shall be stored for 2 000 h without operation at either the minimum or maximum temperature, as specified, of the rated operating temperature range ±3 °C.

After the test period the resonator shall be kept at standard atmospheric conditions for testing until thermal equilibrium has been reached.

The specified test shall be carried out and the final measurements shall be within the limits specified in the detail specification.

4.6.2 High temperature ageing (non-destructive)

The resonator shall be maintained at (85 ± 3) °C for a continuous period of 30 days unless specified in the detail specification.

After the test the resonator shall be kept at standard atmospheric conditions for testing until thermal equilibrium has been reached.

The specified test shall be carried out and the final measurements shall be within the limits specified in the detail specification.

4.6.3 Robustness of terminations (destructive)

The test shall be performed for resonators with terminations, for example TEM mode resonators, in accordance with test Ua_1: Tensile, and test Ua_2: Thrust, of IEC 60068-2-21.

4.6.4 Soldering

4.6.4.1 Resistance to soldering heat and to dissolution of metallization

Under consideration:

The test method of resistance to soldering heat and to dissolution of metallization of SMDs using a solder bath is given in IEC 60068-2-58. But this test may not be applicable to the large size devices with large heat capacity. The test methods such as the reflow soldering method and the hot plate method are proposed for SMDs which shall be assessed for reflow processes only in IEC 60068-2-58. The methods will be applied for the test of resistance to soldering heat and to dissolution of metallization.

4.6.4.2 Solderability of terminations

Test A: Solder bath method.

The test shall be performed in accordance with Method 1 of Test Ta: Solderability of wire and tag terminations, of IEC 60068-2-20. The solder bath shall be heated to (235 ± 5) °C, unless otherwise specified.

Test B: Soldering iron method.

The method shall be used when the solder bath method is impracticable. The test shall be performed in accordance with Method 2 of Test Ta: Solderability of wire and tag terminations of IEC 60068-2-20.

4.6.4.3 Adhesion strength of metallized electrode

The metallized electrode of the specimen shall be cleaned with suitable organic solvent, then cut to 2 to 10 square millimetres, thereafter completely solder the copper wire to the metallized electrode with the suitable flux.

For silver metallized electrodes, to minimize solder leaching, silver containing solder should be used.

Attach the specimen to the tensile tester or other suitable testing machine, and apply tension load perpendicularly to the metallized electrode. Inspect the separated surface and calculate the adhesion strength T, from the load at the separation of the metallized electrode, by the following formula:

$$T = -\left(\frac{P}{A}\right) \quad \text{Pa/m}^2$$

where

P is load at yield, at the maximum load, at the separate (Pa).

A is area of separated metallized electrode after test (m^2).

4.6.5 Rapid change of temperature (non-destructive)

The test shall be performed in accordance with test Na of IEC 60068-2-14.

The low and high test chamber temperatures are the extreme temperatures of the operating range stated in the relevant detail specification, the resonators shall be maintained for 30 min at each temperature extreme. The resonator shall be subjected to five complete thermal cycles and then exposed to standard atmospheric conditions for recovery for not less than 2 h.

4.6.6 Bump (destructive)

This test shall be performed in accordance with test Eb of IEC 60068-2-29. The resonator shall be suitably mounted with clamps on the body. The bumps shall be applied in three mutually perpendicular axes, one of which is parallel to the terminations.

The relevant detail specification shall specify the degree of the severity in accordance with test Eb of IEC 60068-2-29.

4.6.7 Vibration (destructive)

The test shall be performed in accordance with test Fc of IEC 60068-2-6. The resonator shall be suitably mounted as required by the detail specification. The vibration shall be applied in three mutually perpendicular axes, one of which is parallel to the terminations.

The relevant detail specification shall specify the degree of severity in accordance with test Fc, of IEC 60068-2-6.

4.6.8 Shock (destructive)

The test shall be performed in accordance with test Ea of IEC 60068-2-27. The resonator shall be suitably mounted as required by the detail specification. The shock shall be applied in three mutually perpendicular axes, one of which is parallel to the terminations.

The relevant detail specification shall specify the degree of severity in accordance with test Ea, of IEC 60068-2-27.

4.6.9 Acceleration, steady state (non-destructive)

The test shall be performed in accordance with test Ga of IEC 60068-2-7. The resonator shall be mounted as required by the detail specification. The procedure and severity shall be stated in the relevant detail specification.

4.6.10 Climatic test (destructive)

The tests described in 4.6.11 to 4.6.13 can be performed as a climatic sequence test according to Clause 7 of IEC 60068-1. Where applicable, each test can be performed as an individual test.

4.6.11 Dry heat

The tests shall be performed in accordance with Test Ba of IEC 60068-2-2, at (85 ± 2) °C for 16 h, unless otherwise stated in the relevant detail specification.

4.6.12 Damp heat, cyclic

The test shall be performed in accordance with test Db, variant 1 of IEC 60068-2-30, for one cycle of 24 h, unless otherwise stated in the relevant detail specification.

4.6.13 Cold

The test shall be performed in accordance with Test Aa of IEC 60068-2-1, at (–40 ± 3) °C for 2 h, unless otherwise stated in the relevant detail specification.

4.6.14 Damp heat, steady state

The test shall be performed in accordance with test Ca of IEC 60068-2-78, using a degree of severity corresponding to the climatic category of the resonator under test.

4.6.15 Low air pressure

The test shall be performed in accordance with test M of IEC 60068-2-13, unless otherwise stated in the relevant detailed specification.

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