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First edition
2004-07

Filters using waveguide type dielectric resonators –

Part 2: Guidance for use

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CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

FILTERS USING WAVEGUIDE TYPE DIELECTRIC RESONATORS –

Part 2: Guidance for use

FOREWORD

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International Standard IEC 61337-2 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
49/665/FDIS	49/683/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 61337 consists of the following parts under the general title *Filters using waveguide type dielectric resonators:*

Part 1: Generic specification;[1]

Part 1-1: General information, standard values and test conditions – General information and standard values;[2]

Part 1-2: General information, standard values and test conditions – Test conditions;[2]

Part 2: Guidance for use;

Part 3: Standard outlines[3].

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- withdrawn;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 may be issued at a later date.

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1 To be published.

2 To be merged and replaced by IEC 61337-1 in the near future.

3 Under consideration.

INTRODUCTION

This part of IEC 61337 gives practical guidance on the use of filters using waveguide type dielectric resonators that are used in telecommunications and radar systems. Refer to IEC 61337-1-1 and IEC 61337-1-2 for general information, standard values and test conditions.

These dielectric filters have the features of small size, low loss, high reliability and high stability against temperature and ageing. Dielectric filters are suitable for applications such as mobile communication service, mobile satellite communication service, microwave terrestrial communication service, and fixed satellite communication service. In particular, they are now widely used for duplexers and filters of portable phones and cellular base stations.

This standard has been compiled in response to a generally expressed desire on the part of both users and manufacturers for guidance for the use of filters using waveguide type dielectric resonators, so that the filters may be used to their best advantage. For this purpose, general and fundamental characteristics have been explained in this standard.

FILTERS USING WAVEGUIDE TYPE DIELECTRIC RESONATORS –

Part 2: Guidance for use

1 Scope

The scope of this part of IEC 61337 is limited to filters using waveguide type dielectric resonators that are used for microwave applications such as portable phones, cellular base stations and radio links.

It is not the aim of this standard either to explain the theory or to attempt to cover all the eventualities that may arise in practical circumstances. This standard draws attention to some of the more fundamental questions which should be considered by the user before he places an order for dielectric filters for a new application. Such a procedure will be the user's insurance against unsatisfactory performance.

Standard specifications, such as those given in IEC 61337, and national specifications or detail specifications issued by manufacturers, will define the available combinations of mid-band frequency, pass band, insertion attenuation, pass-band ripple, return attenuation, spurious response, operating power, and so on. These specifications are compiled to include a wide range of dielectric filters with standardized performances. It cannot be over-emphasized that the user should, wherever possible, select his dielectric filters from these specifications, when available, even if it involves making small modifications to his circuit to enable standard filters to be used.

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 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 60068-2-6:1975, *Environmental testing – Part 2: Tests. Test Fc: Vibration (sinusoidal)*

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

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

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

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

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

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

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

IEC 60068-2-58:1999, *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 60068-2-78:2001, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 61337-1-1, *Filters using waveguide type dielectric resonators – Part 1-1: General information, standard values and test conditions – General information and standard values*

IEC 61337-1-2, *Filters using waveguide type dielectric resonators – Part 1-2: General information, standard values and test conditions – Test conditions*

3 Application guide for filters using waveguide type dielectric resonators

3.1 Classification of filters using waveguide type dielectric resonators

Filters using waveguide type dielectric resonators are classified into six types: $TE_{01\delta}$ mode dielectric filter, TM mode dielectric filter, TEM mode coaxial dielectric filter, stripline and microstripline dielectric filter, and multilayered chip-type filter.

These dielectric filters are classified according to their operating power and the unloaded Q of their resonance mode. Figure 1 shows the relationship between the unloaded Q and the maximum power durability for these filters in practical applications.

High-power durability of up to 100 W is the advantage of dielectric filters. The maximum operating power, however, should be limited by the construction of filters and by the Q value of the dielectric resonator used for the filters, because higher operating power causes a temperature rise that results in inferior electric characteristics such as a shift of mid-band frequency and an increase in insertion attenuation.

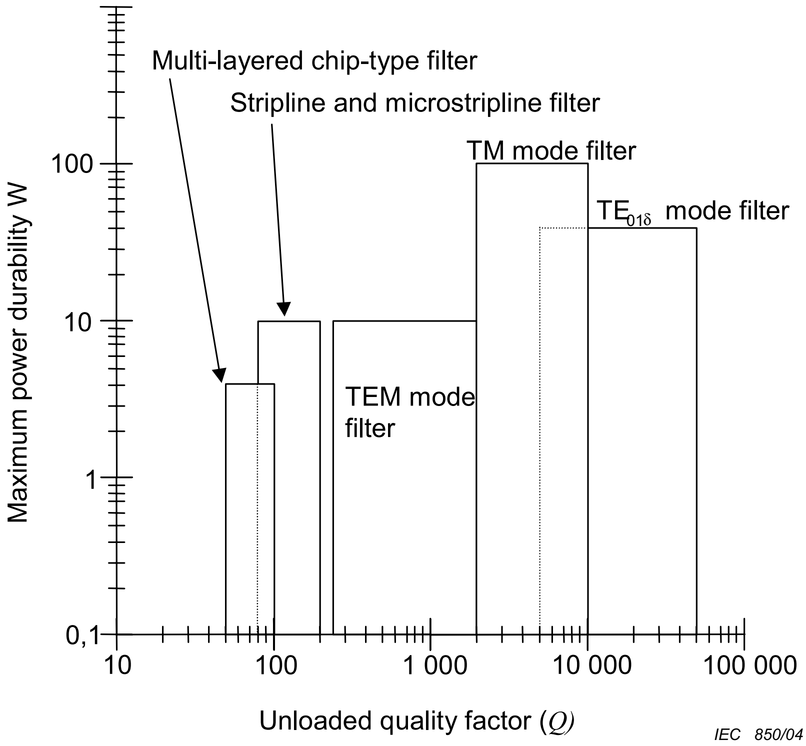


Figure 1 – Typical unloaded Q and maximum operating power of dielectric filters

3.2 Practical remarks for filters using waveguide type dielectric filters

3.2.1 $TE_{01\delta}$ mode dielectric filter

a) Features of the $TE_{01\delta}$ mode dielectric filter

The $TE_{01\delta}$ mode resonator obtains very high unloaded Q, as most of the resonance energy is stored in the dielectric element, and the copper loss due to the resistivity of the shielding conductor is minimized.

Figure 2 shows an example of the practically equivalent unloaded Q for the $TE_{01\delta}$ mode dielectric filter compared with the TE_{101} mode metal cavity. High unloaded Q from 5 000 to 10 000 is obtained by using high Q dielectric resonator materials with characteristics such as an ε' of 30 and a Q × f value of 150 000 GHz, or an ε' of 25 and a Q × f value of 300 000 GHz.

Using these $TE_{01\delta}$ mode dielectric resonators, miniaturized dielectric filters with low insertion attenuation and high temperature stability are realized at the frequency range from 1 GHz to 20 GHz. The relative bandwidth of the $TE_{01\delta}$ mode dielectric band-pass filter is usually less than 1 % of the mid-band frequency.

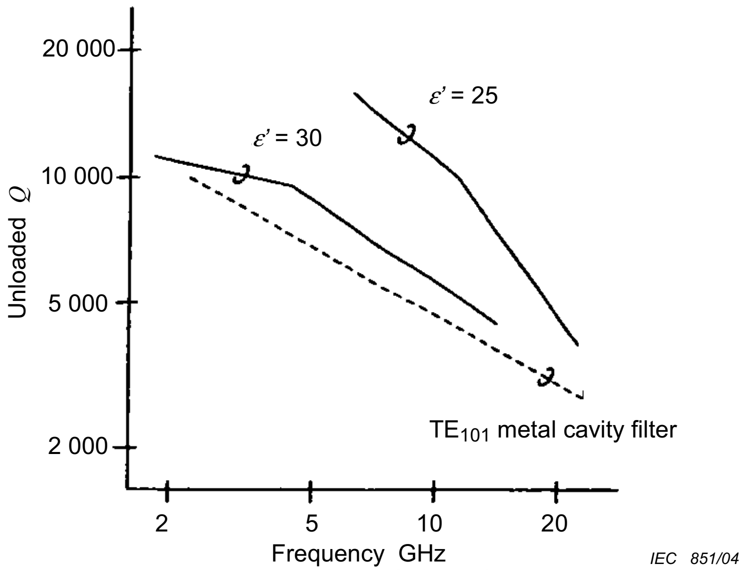


Figure 2 – Example of practically equivalent unloaded Q of a $TE_{01\delta}$ mode dielectric filter compared with a TE_{101} mode metal cavity filter

b) Construction of the $TE_{01\delta}$ mode dielectric filter

Figure 3 shows an example of the $TE_{01\delta}$ mode dielectric band-pass filter. Plural pieces of columnar or cylindrical dielectric resonators are fixed in a metal case.

The dimensions a and b of the filter are determined to constitute the cut-off waveguide of the dominant TE_{10} mode. The adjustment of the mid-band frequency by the trimming screw is less than 1 % of the mid-band frequency for the dielectric filter, while the adjustment of the mid-band frequency for the TE_{101} mode waveguide filter is 5 %.

Figure 4 shows an example of the $TE_{01\delta}$ mode dielectric band-stop filter. The columnar or cylindrical dielectric resonators are coupled with the microstrip line. The resonators are fixed at the three-quarters wavelength interval along the microstrip line.

The high unloaded Q of the dielectric resonators realizes the narrow bandwidth and the low insertion loss in the neighbouring frequency of the rejection band of the $TE_{01\delta}$ mode dielectric band-stop filter.

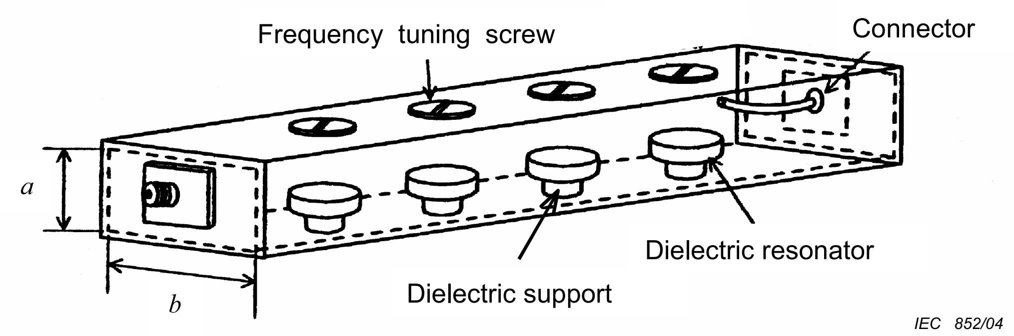


Figure 3 – Example of a $TE_{01\delta}$ mode dielectric band-pass filter

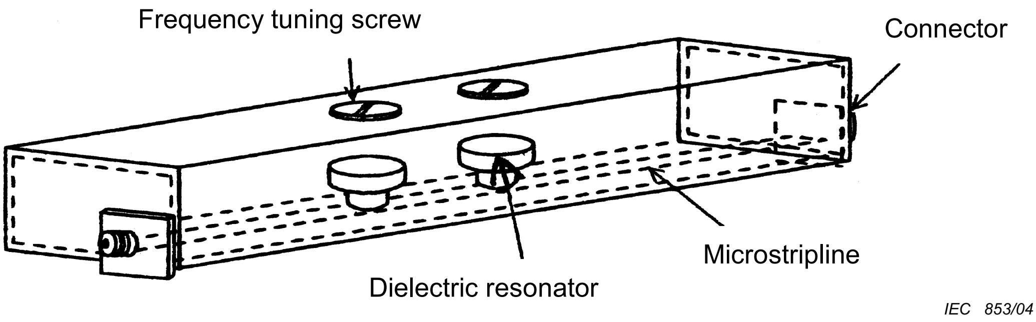


Figure 4 – Example of a $TE_{01\delta}$ mode dielectric band-stop filter

c) Characteristics of the $TE_{01\delta}$ mode dielectric filter

In the case of the $TE_{01\delta}$ mode dielectric filter, deterioration of the attenuation characteristics are caused by the unnecessary spurious resonances that exist over 1,2 times the mid-band frequency.

Figure 5 shows an example of the spurious response of the $TE_{01\delta}$ mode dielectric band-pass filter. This spurious response can be suppressed by using the quarter wavelength coaxial resonance elements for the first and last resonators of the filter. Figure 6 shows an example of the filter with the coaxial resonance elements.

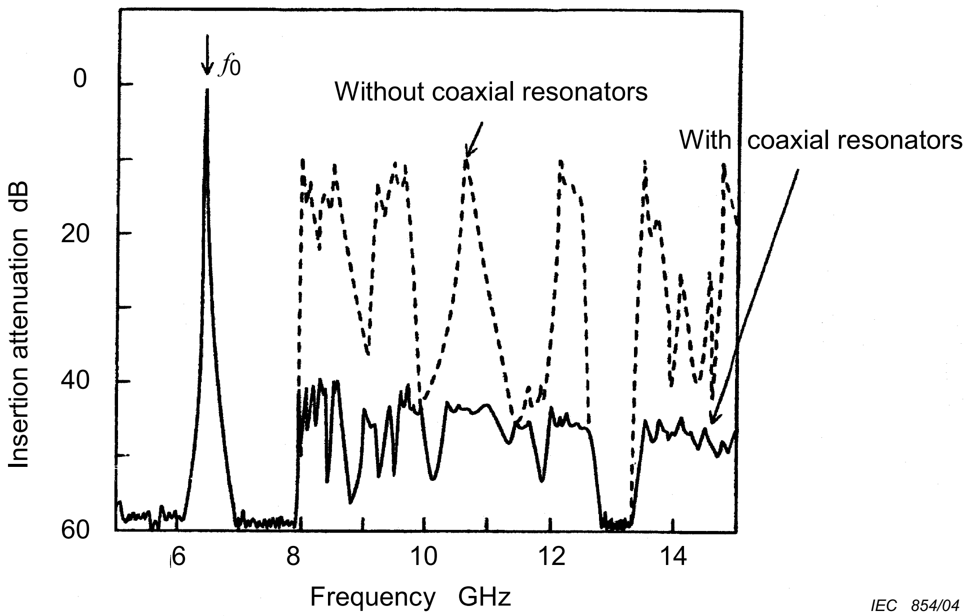


Figure 5 – Example of spurious responses for the $TE_{01\delta}$ mode dielectric band-pass filter

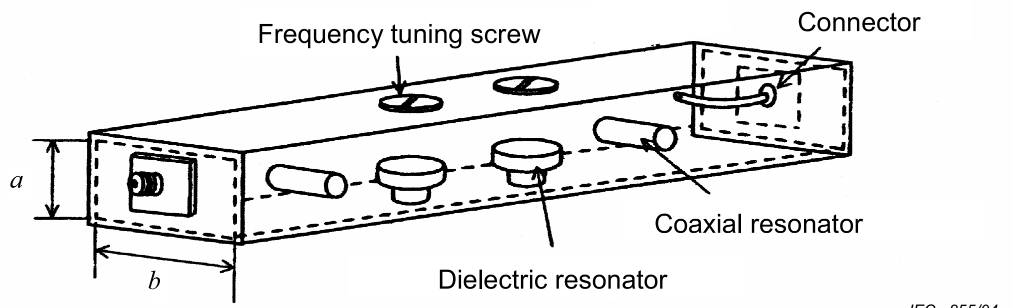


Figure 6 – Example of a $TE_{01\delta}$ mode dielectric band-pass filter with quarter wavelength coaxial resonators

3.2.2 TM mode dielectric filter

a) Features of the TM mode dielectric filter

Figure 7 shows the construction of the TM_{010} and the TM_{110} mode dielectric resonators. These resonators are often used for high-power applications such as filters for cellular base stations, due to the construction that aids in the release of heat.

As the electric field passes from the bottom to the top of the shielding conductor, undesirable frequency shift is caused if the air gap arises between the dielectric and the shielding conductor due to the difference of the thermal-expansion coefficients. To solve this problem, the practical TM mode resonator and the shielding cavity are made of a mono-block structure using the same dielectric material. The silver conductor is fired on the surface of this dielectric cavity. This mono-block structure realizes high temperature stability of the resonance frequency and high reliability for the release of heat.

The dielectric resonator materials used for the filters of cellular base stations must have low tanδ to restrain the heat generation and low intermodulation distortion level to restrain the interference between plural signals.

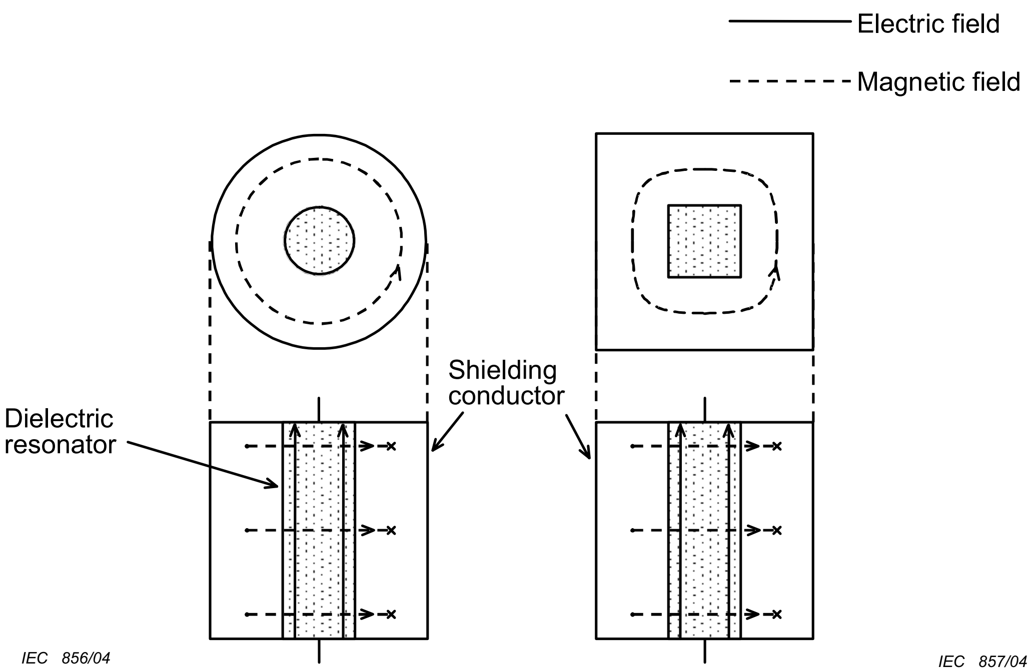


Figure 7a – TM_{010} mode

Figure 7b – TM_{110} mode

Figure 7 – TM_{010} and TM_{110} mode dielectric resonators

The materials with low tanδ have a low third-harmonic distortion level. Figure 8 shows the third-harmonic distortion level at 800 MHz for three kinds of dielectric resonator materials. (Zr,Sn)TiO_4 material with an ε' of 38 and a $Q \times f$ value of 50 000 has the low distortion level of –150 dBc at a field intensity of 50 V/mm, which can be used for filters of cellular base stations.

b) Construction of the TM mode dielectric filter

Figure 9 shows examples of an antenna filter and an antenna duplexer for cellular base stations. The antenna filter is made of six TM_{110} mode dielectric resonators.

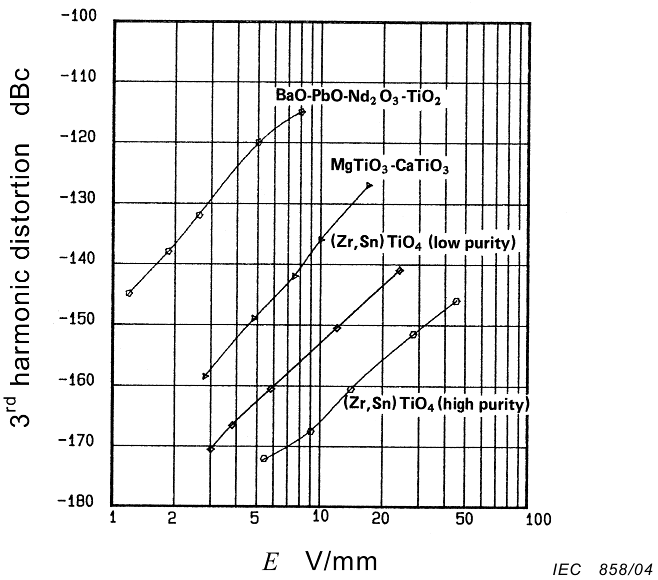


Figure 8 – Example of the third-harmonic distortion level of dielectric resonator material at 800 MHz

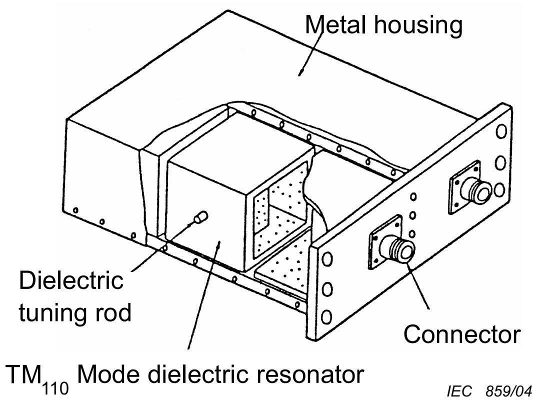


Figure 9a – Antenna filter

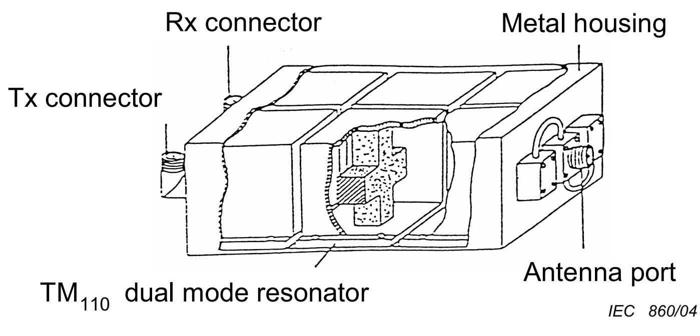


Figure 9b – Antenna duplexer

Figure 9 – Example of an antenna filter and an antenna duplexer for cellular base stations

The antenna duplexer is composed of six sections Tx filter and Rx filter, each of which is made of three TM_{110} dual-mode dielectric resonators.

One TM_{110} dual-mode resonator works as two TM_{110} single-mode resonators. The volume of this duplexer is one-half of the duplexer using the TM_{110} single-mode resonators.

c) Characteristics of the TM mode dielectric filter

The characteristics of the duplexer shown in Figure 9b are 900 MHz of the mid-band frequency, 100 W of the maximum applied power, and –160 dBc of the third intermodulation distortion level under the two-tone applied powers, each of which is 30 W. Its dimension is 87 mm × 54 mm × 13 mm.

3.2.3 TEM mode coaxial dielectric filter

a) Features of the TEM mode dielectric filter

Miniaturized dielectric filters using the quarter wavelength TEM mode dielectric resonators are popularly used for the duplexer of portable phones. They are also used for wireless local area network systems. These filters have the advantages of low insertion attenuation, high attenuation characteristics, low frequency drift against temperature and high-power availability.

The unloaded Q (Q_u) of the quarter wavelength TEM mode resonator is given by the following equation:

$$\frac{1}{Q_u} = \frac{1}{Q_0} + \frac{1}{Q_C} \tag{1}$$

where

Q_0 is the quality factor due to the tanδ of the material; and

Q_C is the quality factor due to the conduction loss of the shielding conductor.

$$Q_0 = 1/\tan\delta \tag{2}$$

$$Q_C = \sqrt{2\sigma\omega_0\mu_0} \cdot \frac{\ln(b/a)}{2/a + 2/b + (2/L)\ln(b/a)} \tag{3}$$

where

σ is the conductivity of the shielding conductor;

a is the outer diameter of the quarter wavelength TEM mode resonator;

b is the inner diameter of the quarter wavelength TEM mode resonator; and

L is the length of the quarter wavelength TEM mode resonator.

As the Q_0 of the quarter wavelength TEM mode resonator is much higher than the Q_C, its unloaded Q is almost determined by Q_C. The larger a, b and L give a higher Q_C and consequently a higher unloaded Q of this resonator. Figure 10 shows practically obtained unloaded Q as a function of frequency. The resonator with a lower ε' has a longer length at the same resonance frequency, which results in the higher unloaded Q.

b) Construction of the TEM mode dielectric filter

Figure 11 shows an example of two types of antenna duplexers for portable phones: the discrete-type duplexer and the block-type duplexer. These duplexers are surface-mounted on the circuit-board by the I/O terminals.

The discrete-type duplexer is made of plural TEM mode resonators, which are capacitively or inductively coupled to each other on a copper-plated resin board.

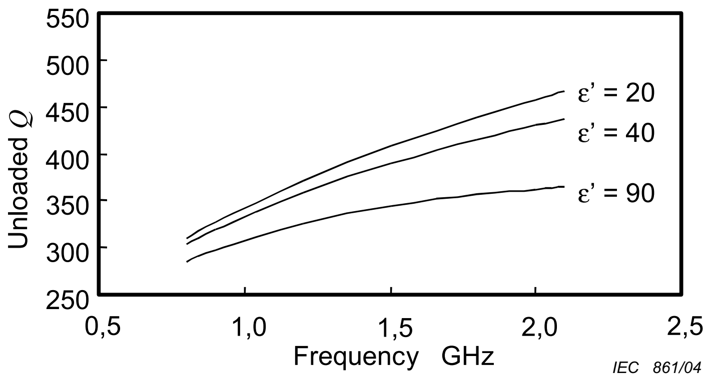


Figure 10 – Practically obtained unloaded Q of quarter wavelength TEM mode dielectric resonators with an ε' of 20, 40 and 90 (outer diameter = 3 mm; inner diameter = 1 mm; practical conductivity of shielding conductor = 4,8 × 10^7 [S/m])

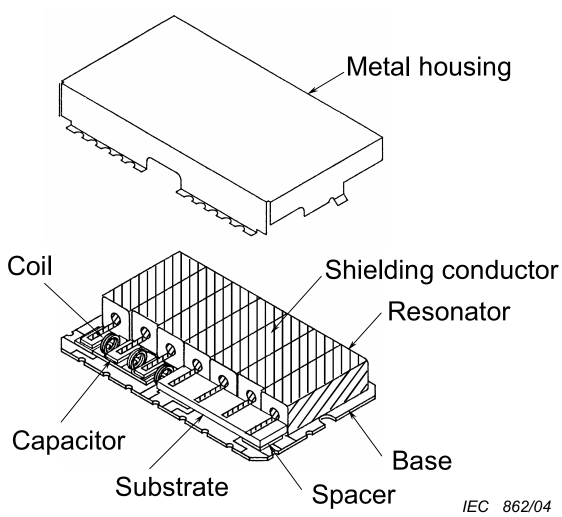


Figure 11a – Discrete-type duplexer

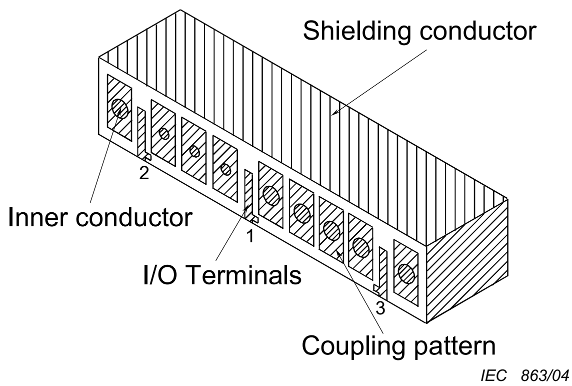


Figure 11b – Block-type duplexer

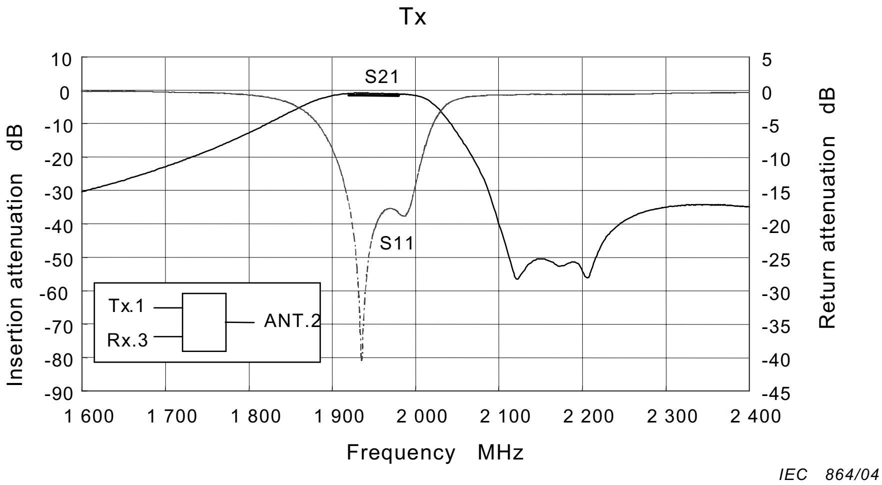
Figure 11 – Examples of antenna duplexers for portable phones using a TEM mode dielectric resonator

The block-type duplexer is made of a monolithic dielectric block with plural holes. The interior of the holes and the exterior of the block except the front end are metal-plated. At the front end, the resonators are capacitively coupled to each other through the patterns of electrodes.

The block-type duplexer has the advantage of lower height over the discrete-type duplexer, because metal housing is unnecessary for this duplexer.

c) Characteristics of the TEM mode dielectric filter

Figure 12 shows an example of the attenuation characteristics of a block-type duplexer of the wideband CDMA portable phone. Its insertion attenuations in the Tx and Rx pass-band width are 1,5 dB and 2,4 dB, respectively, in the temperature range from –35 °C to 85 °C. The maximum ripples are 1,0 dB in both of the Tx and Rx pass-bandwidths. The dimension of this duplexer is 12,6 mm × 5,3 mm × 1,9 mm.



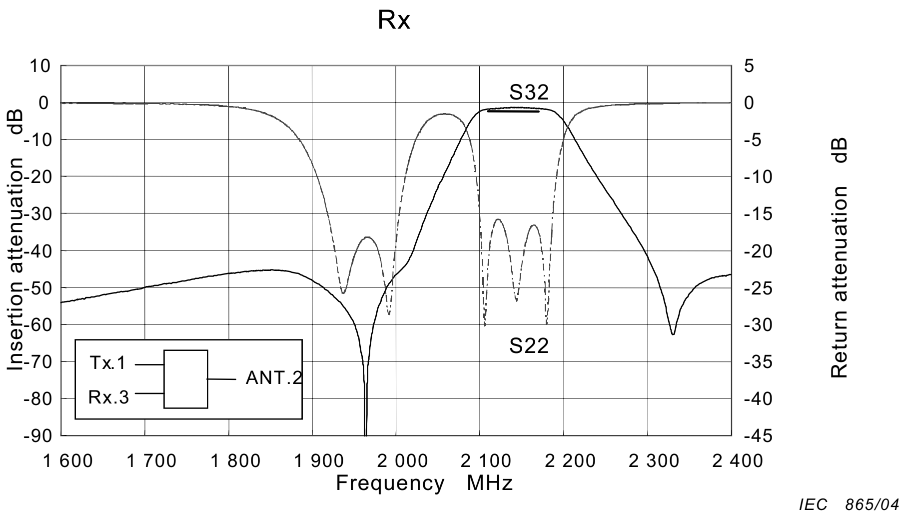


Figure 12 – Examples of the attenuation characteristics of a block-type duplexer for a wideband CDMA portable phone

3.2.4 Chip-type multilayered dielectric filter

a) Features of the chip-type multilayered dielectric filter

The chip-type multilayered dielectric filter is popularly used in portable phones as a low-pass filter on the transmitting side to eliminate the spurious responses or as an interstage band-pass filter on the receiving side.

The advantages of this filter are small size, light weight, and easy handling for the surface mount device. The disadvantages are the relatively high insertion attenuation due to its low unloaded Q of around 100, and the limitation of maximum sections, generally three sections, due to the inferior adjustment structure of inside electrodes.

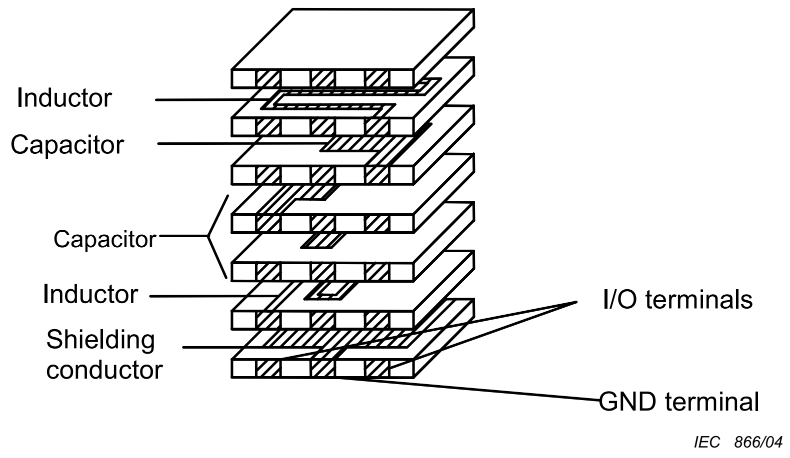


Figure 13a – Lumped-element type filter

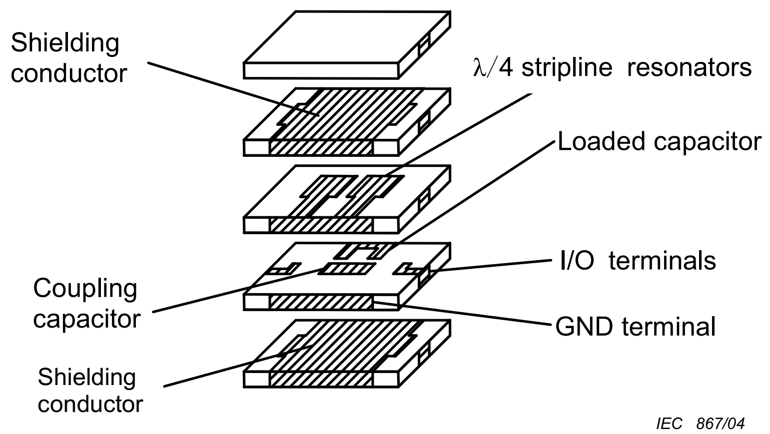


Figure 13b – Distributed-constant type filter

Figure 13 – Example of a chip-type multilayered dielectric band-pass filter

b) Construction of the chip-type multilayered dielectric filter

Figure 13 shows the construction of a chip-type multilayered filter. The conductive patterns are printed on dielectric sheets and they are stacked and co-fired together.

The chip-type filter is classified into two types. One is called the lumped-element filter that is made of the L and C conductive patterns. The dielectric materials of this filter generally have an ε' of between 7 and 10. The other is called the distributed-constant type filter that is made of the quarter wavelength stripline resonators. The dielectric materials of this filter has a higher ε' of between 20 and 80 to miniaturize the filter.

It is preferable to use the foot pattern recommended by each supplier, which removes the unmatched impedance or the undesirable stray capacitance and achieves the prescribed characteristics.

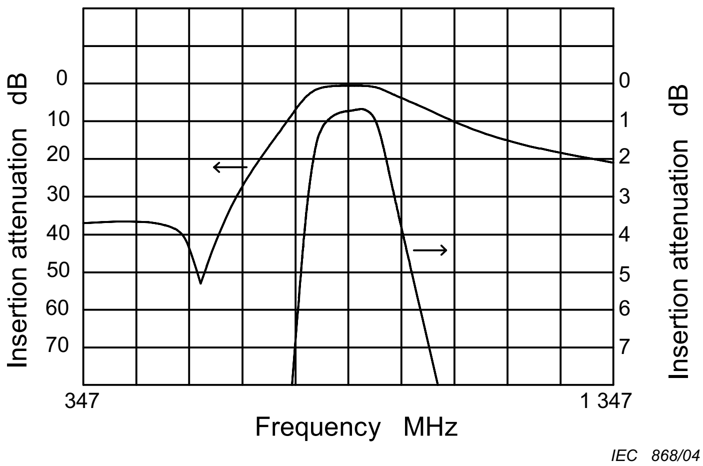


Figure 14a – Attenuation characteristics of an 800 MHz band-pass filter

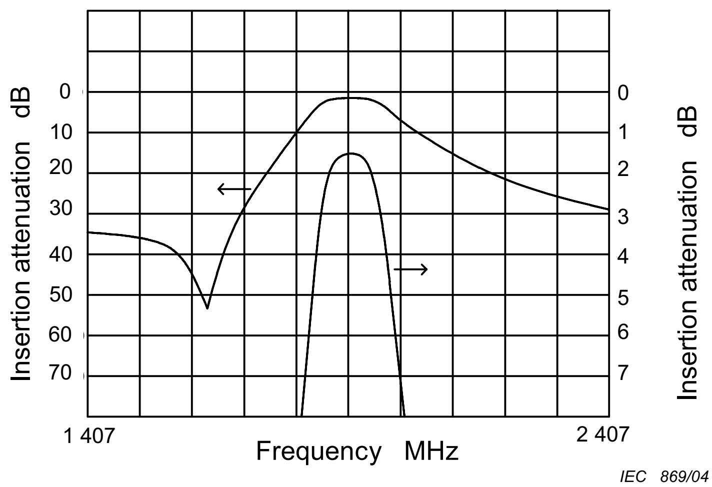


Figure 14b – Attenuation characteristics of a 1,9 GHz band-pass filter

Figure 14 – Example of the attenuation characteristics of a chip-type multilayered dielectric filter

c) Characteristics of the chip-type multilayered dielectric filter

Figure 14 shows examples of the characteristics for band-pass chip-type filters with mid-band frequencies of 800 MHz and 1,9 GHz. These filters have an insertion attenuation of between 1 dB and 2 dB. Their typical dimensions are 4,5 mm × 3,2 mm × 2,0 mm and 2,0 mm × 1,2 mm × 1,0 mm, respectively.

3.2.5 Stripline and microstripline dielectric filters

a) Features of stripline and microstripline dielectric filters

Stripline and microstripline dielectric filters are preferably used in planar and integrated circuits. They have wide flexibility in designing the strip conductor patterns that realizes the varieties of transmission characteristics.

These filters cover the frequency range from 300 MHz to 30 GHz and the maximum operating power up to 10 W. They can also realize the broad pass bandwidth from 5 % to 50 % as a fractional bandwidth, by their close coupling between neighbouring resonators. Their insertion attenuation, however, is relatively high compared with the $TE_{01\delta}$, TM, and TEM mode dielectric filters due to the lower unloaded Q of the stripline and microstripline resonators.

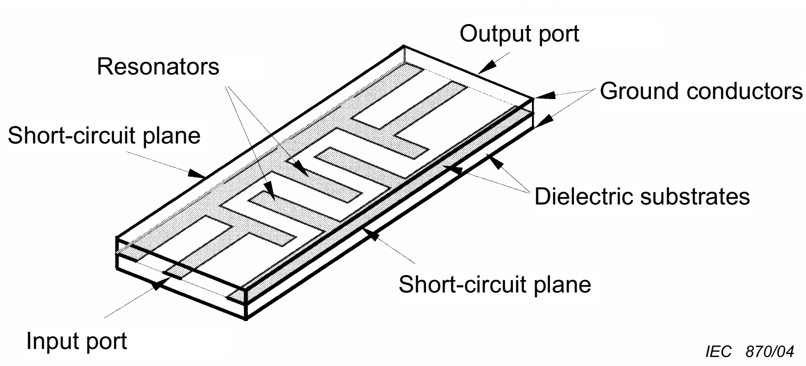


Figure 15a – Stripline dielectric filter

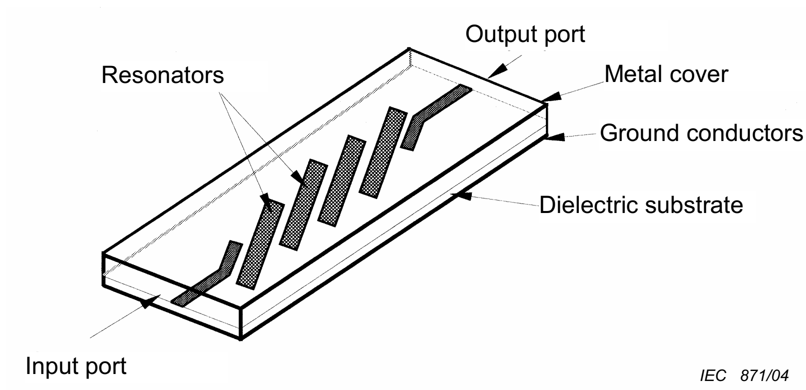


Figure 15b – Microstripline dielectric filter

Figure 15 – Schematic configurations of stripline and microstripline dielectric filter

b) Construction of the stripline and microstripline dielectric filters

Figures 15a and 15b show the schematic configuration of the stripline and microstripline band-pass filters, respectively.

In the case of the stripline filter, the strip conductor patterns are sandwiched between two layered dielectric substrates. PTFE or low-temperature co-fired ceramics (LTCC) are commonly used for the dielectric materials. These materials have an ε' from 2 to 10 and a relatively low dielectric loss. They can be stacked or co-fired with high-conductivity metals such as Ag, Cu, or Au.

The distance between the upper and lower outer conductors of this filter is designed to be short so that the higher order modes could be suppressed over the operating frequency band including the attenuation band. In addition, the upper and the lower ground conductors are short-circuited by metal walls or by through-hole rows, which suppress the parallel waveguide modes.

In the case of the microstripline dielectric filter, the strip conductor patterns are formed on the front surface of a dielectric substrate by a high-precision photo-etching technique, and a metal cover is attached in order to reduce the radiation loss and to obtain sharp attenuation characteristics outside the pass-band.

The width of the metal cover is designed to be less than a half-wavelength of the upper-limit frequency in the operation band for suppressing the waveguide modes. Materials such as polytetrafluoroethylene (PTFE) or low-loss alumina ceramics are commonly used for the substrate. Thinner substrate suppresses the surface radiation mode and an ε' higher than 5 is desirable to obtain sufficient electric-field concentration in the dielectric substrates.

c) Characteristics of the stripline and microstripline dielectric filters

Figure 16 shows an example of the conductor pattern and attenuation characteristic of a parallel-coupled stripline band-pass filter. The resonators are made of the half-wavelength striplines open-circuited at both ends. This filter does not need any adjustment structure as the long resonator elements have the advantage in the dimensional production dispersion.

In the transmission characteristics, the lowest spurious response appears at $2f_0$ where f_0 is the mid-band frequency of the first pass band.

Figure 17 shows an example of the conductor pattern and attenuation characteristic of an interdigital band-pass filter. The resonators are made of quarter wavelength striplines, one end of which is short-circuited and the other end open-circuited. The lowest spurious response of this filter appears at $3f_0$.

Figure 18 shows an example of the conductor pattern and attenuation characteristic of a comb-line band-pass filter. The resonators are made of one-eighth wavelength striplines, one end of which is short-circuited and the other end loaded with a lumped capacitor. The lowest spurious response of this filter appears at about $3f_0$ and $5f_0$.

Figure 19 shows an example of the conductor pattern and attenuation characteristic of a band-stop filter. The resonators are made of stripline resonator stubs, one end of which is short-circuited and the other capacitively coupled with the main stripline.

The resonance frequency of the resonator stub is adjusted so that the maximum transmission attenuation is obtained at the mid-band frequency of the stop band.

As practical values, the three-section band-pass filters have an insertion attenuation of between 0,5 dB and 1,5 dB with a mid-band frequency of 2 GHz and a fractional bandwidth of 10 %, and the stop-band filter has an insertion attenuation of greater than 50 dB. These attenuation characteristics are the function of the operating frequency, pass bandwidth, number of resonators, and unloaded Q of resonators.

The characteristics of microstripline dielectric filters are relatively inferior to those of stripline dielectric filters, because thinner substrates must be used to suppress the surface radiation mode. Conductor patterns similar to the stripline filters are used for the microstripline dielectric filters.

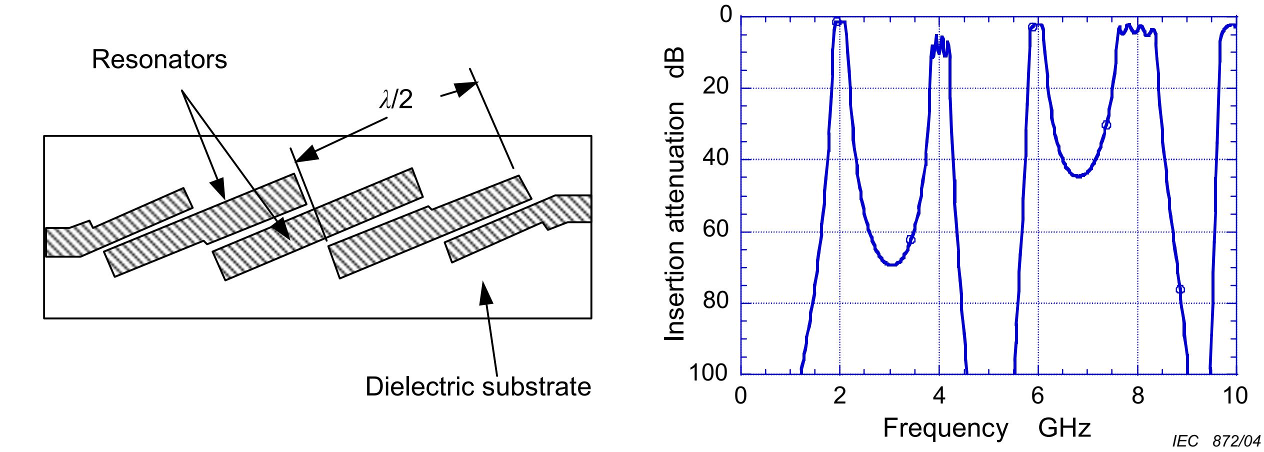


Figure 16 – Example of the conductor pattern and attenuation characteristic of a parallel-coupled band-pass stripline filter

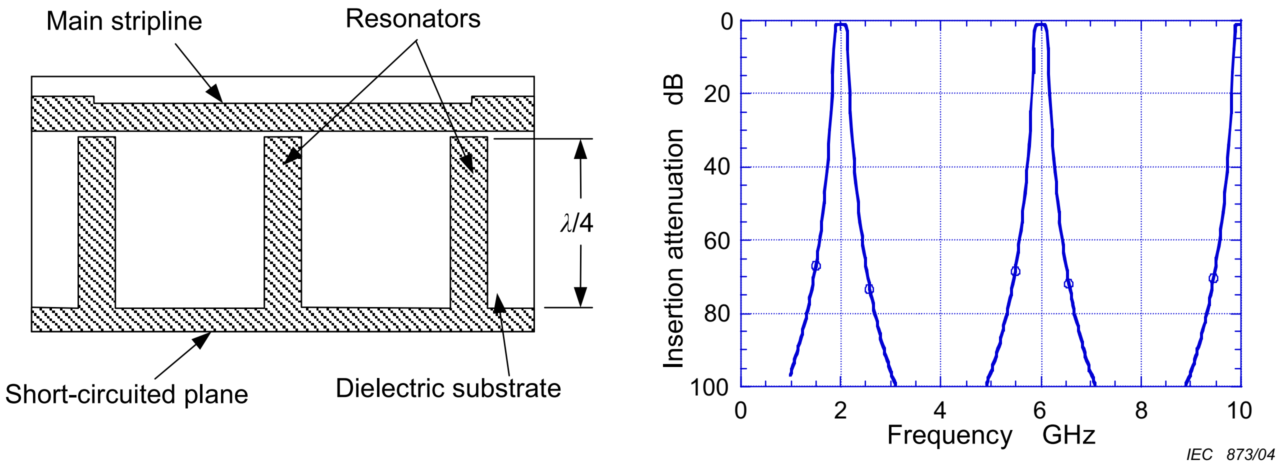


Figure 17 – Example of the conductor pattern and attenuation characteristic of an interdigital band-pass stripline filter

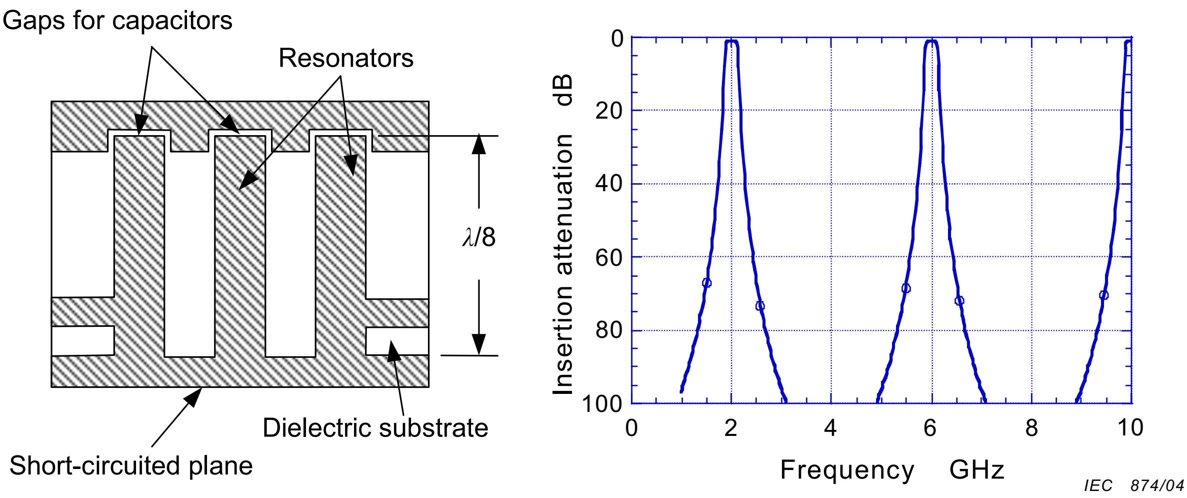


Figure 18 – Example of the conductor pattern and attenuation characteristic of a comb-line band-pass stripline filter

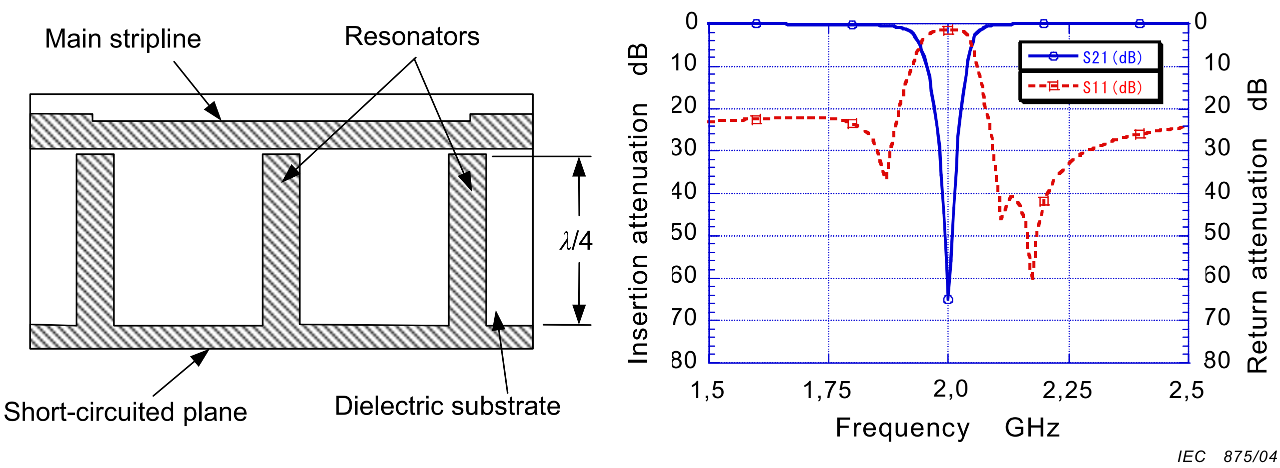


Figure 19 – Example of the conductor pattern and attenuation characteristic of a band-stop stripline filter

4 Checklist of dielectric resonator specification

The following checklist provides guidance for the manufacturer to complete specifications for a particular dielectric filter, including parameters and operating environmental characteristics. It will also be useful for operation of the filter and for drawing up specifications. The prospective user is then able to more accurately evaluate the applicability of the filter to his intended use. The list also assists the user when he finds it necessary to specify a new dielectric filter for a particular application, by alerting him to the various operating conditions and performance characteristics that need definition.

When a standard item can meet the requirements, it will be sufficient to specify the corresponding specifications. When the existing detail specifications cannot wholly meet the requirements, the specifications should be referred to, together with a list of known differences.

In rare cases where it is not reasonable to quote the differences to the existing detail specifications, new specifications are to be prepared in a format similar to those already used for a standard detail specification.

Clearly, it is not necessary to specify all of the parameters listed for every application. Only those that are of importance in a particular case should be imposed. Specifications regarding non-critical parameters, as well as the imposition of unnecessarily close tolerances, would result in excessive costs.

In Table 1, reference is made to the relevant clauses and subclauses of IEC 60068-1, IEC 60068-2, IEC 61337-1-1, and IEC 61337-1-2.

4.1 Checklist

Table 1 – References to relevant publications

	Relevant IEC publications, clauses and subclauses
Electrical characteristics	
Transmission characteristics at standard atmospheric conditions	61337-1-2, 5.2.1
Transmission characteristics as a function of temperature	61337-1-2, 5.2.2
Return characteristics at standard atmospheric conditions	61337-1-2, 5.2.3
Insulation resistance	61337-1-2, Clause 6
Voltage proof	61337-1-2, Clause 7
Power capability	61337-1-2, Clause 8
Environmental characteristics	
Storage test	61337-1-2, Clause 9
High temperature ageing	61337-1-2, Clause 10
Rapid change of temperature	61337-1-2, Clause 13, 60068-2-14
Bump	61337-1-2, Clause 14, 60068-2-29
Vibration	61337-1-2, Clause 15, 60068-2-6
Shock	61337-1-2, Clause 16, 60068-2-27
Acceleration, steady state	61337-1-2, Clause 17, 60068-2-7
Climatic tests	61337-1-2, Clause 18, 60068-1
Dry heat	61337-1-2,18.1, 60068-2-2
Damp heat, cyclic	61337-1-2,18.2, 60068-2-30

	Relevant IEC publications, clauses and subclauses
Cold	61337-1-2,18.3, 60068-2-1
Damp heat, steady state	61337-1-2, Clause 19, 60068-2-78
Low air pressure	61337-1-2, Clause 20, 60068-2-13
Other factors	
Physical characteristics	
Strength of terminations	61337-1-2, Clause 11, 60068-2-21
Tensile test and thrust test	61337-1-2, 11.1
Bend test	61337-1-2, 11.2
Torque test	61337-1-2, 11.3
Solderability (where applicable)	61337-1-2, Clause 12, 60068-2-20
Resistance to soldering heat and to dissolution of metallization	61337-1-2, 12.1, 60068-2-58
Solderability of terminations	61337-1-2, 12.2
Other factors	
Inspection requirements	
Applicable documents (related specifications)	61337-1-2, Annex A
Inspection authority	61337-1-2, Annex A
Type test	
Type test procedure	61337-1-1, Clause 5
Acceptable quality level	
Marking	
Other factors	

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