GENERAL INFORMATION

General information on the use of dielectric resonators

Dielectric resonators are mainly designed to replace resonant cavities in microwave circuits (filters, oscillators, etc.). Like resonant cavities, they present the following features:

- resonant modes of frequency determined by the dimensions,
- high Q-factors.

But they also have the following advantages:

- more compact,
- higher temperature stability,
- easy to use.

The main difference lies in the fact that the wavelength in dielectric materials is divided by the square root of the permittivity. Moreover, unlike resonant cavities, the reactive power stored during resonance is not strictly confined inside the resonator. The leakage fields from the resonator can be used for coupling or adjusting the frequency.

With an isolated resonator, these leakage fields produce a radiation which may be useful (to produce an antenna for example) but which must be eliminated by metal shielding - in most applications - in order to prevent any decay of the quality factor. The design of the shield plays a very important part in final performances such as insertion loss, spectral purity, temperature stability and spurious mode rejection.

The most commonly used mode is refered to as $TE_{01\delta}$ (fig. 1), which has a rotational symmetry. The encapsulation must respect this symmetry in order to get optimum performances. Other modes not possessing this symmetry can be used for very specific applications. Some are hybrid modes (HE_{111} for example) and the influence of the encapsulation becomes even more important in these cases. Metallized coaxial resonators can also be used in TEM mode for frequencies lower than 2 GHz (please, see our Ceramic Coaxial Resonator catalog (page 37)

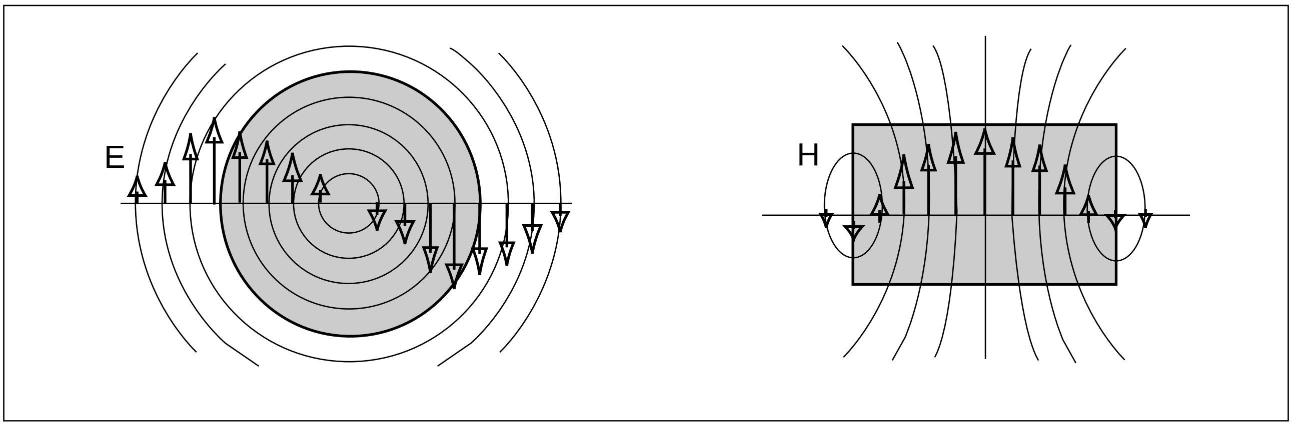


fig. 1 - $TE_{01\delta}$

Dielectric parameters

Dielectric constant : ε'

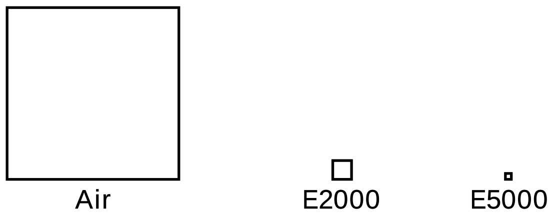
Reflects the capability of a material to confine a microwave. The higher this parameter, the better the confinement.

Example : a given microwave with a particular frequency is confined:

in a 10x10x10 mm air cavity ($\frac{\varepsilon'_{air}}{\varepsilon'0}$ = 1),

in a 1.64x1.64x1.64 mm E2000 dielectric resonator ($\frac{\varepsilon'_{E2000}}{\varepsilon'0}$ = 37),

and in a 1.13x1.13x1.13 mm E5000 dielectric resonator ($\frac{\varepsilon'_{E5000}}{\varepsilon'0}$ = 78).



Quality factor: Q

Related to the losses in the material. Losses in the material are represented by:

$$\text{tg}(\partial) = \frac{\varepsilon''}{\varepsilon'}$$

Where ∂ is the loss angle, ε' the dielectric constant and ε" the dielectric losses. Usually, people are talking about the dielectric constant with ε even if the correct designation is ε'. Indeed, ε = ε' + j.ε"

Q is equal to:

$$Q = \frac{1}{\text{tg}(\partial)} = \frac{\varepsilon'}{\varepsilon''}$$

The higher the Q factor, the better the material. A common way for expressing losses, as they are linear with the frequency, is to use the "Q times frequency" factor called Q. Fo, where Fo is the measurement frequency.

Example: typical values for E2000 family are Q = 5000, Fo = 10 GHz and then Q.Fo = 50000.

DIELECTRIC MATERIALS

Dielectric parameters

Temperature coefficient: τf

Gives the material frequency shift among temperature. A resonator is characterized by its resonant frequency. But this parameter varies with temperature. τf reflects these variations:

$$\tau f = \frac{\Delta F}{Fo} \cdot \frac{1}{\Delta T}$$

Where Fo is the resonant frequency (MHz) at ambient temperature, ΔF the frequency variation (MHz) among the ΔT temperature range (°C).

Example: consider a C-band puck with a resonant frequency of 5150 MHz at 20° C. We measure from (-30)° C to 70° C, which corresponds to a ΔT of 100° C. The observed variation ΔF is 2 MHz. So we obtain:

$$\tau f = \frac{2}{5150.100} = 3.9.10^{-6}/° C$$

The material is said to be a 4 ppm/° C one.

Remark: we act as if the frequency variation among temperature was linear. However, there is a non-linearity coefficient and the accurate expression of tf is:

$$\tau f = (a + 2.b.\Delta T)$$

Where "a" is the stability coefficient and "b" the non-linearity coefficient. Our measurement system gives us both the "a" and "b" parameters. But, as "b" is always insignificant when compared to "a", we approximate τf to "a":

$$\tau f = \frac{\Delta F}{Fo.\Delta T} = a + 2.b.\Delta T \approx a$$

Resonant frequency: Fo

A resonator is mainly characterized by its resonant frequency that corresponds to a minimum of dielectric losses. This frequency Fo (GHz) is linked to the material dielectric constant ε' and the volume V (mm^3) of the resonator:

$$Fo \approx \frac{233}{\sqrt{\varepsilon'}.V^{\frac{1}{3}}}$$

Example: let us consider two resonators with the same dimensions:

- E2000 puck (ε'=37), diameter 5.5 mm, height 2.3 mm: this gives us a Fo of 10.1GHz.
- E5000 puck (ε'=78), diameter 5.5 mm, height 2.3 mm, this gives us a Fo of 6.9 GHz.

Characterization

Permittivity measurement

It is important for the user to accurately know the permittivity of the material in order to calculate the dimensions of the resonator which is to operate at a given frequency.
This parameter is measured by the classic **Hakki** and **Coleman** method. A cylindrical sample is placed between two metal discs (fig. 2a). When the disks make contact with the cylinder ends, the expression of the fields continuity conditions can be expressed by a transcendental equation relating resonance frequency, permittivity and resonator size.
This method is extremely accurate since the real field configuration conforms to the theoretical configuration. Moreover, the selection of mode TE_{011} means that there is no fringing fields or contact problem. This mode can be easily identified. Of all the low frequency modes, this is the only one the frequency of which decreases as the metal disk moves away from the resonator. The measurement accuracy is mainly determined by the accuracy of the dimensions, typically 0.1 %.

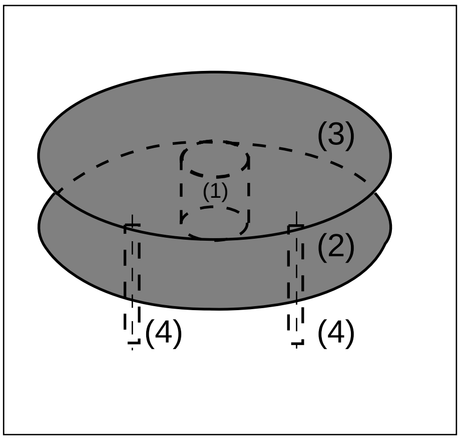


fig. 2a
Permittivity measurement

1. Cylindrical sample
2. Lower metal disk
3. Mobile metal disk
4. Coaxial line terminated by coupling loops
5. Metal cylinder
6. Low permittivity support

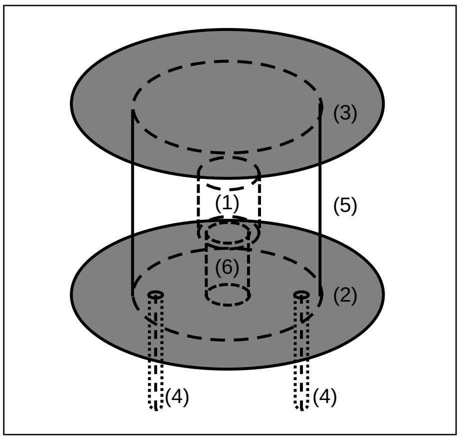


fig. 2b
Dielectric loss measurement

Q-factor measurement

The concepts of Q-factor and dielectric loss tangent can be used interchangeably. The latter is more correct in terms of solid state physics, however the former is more commonly used in microwave circuit design. Three methods can be used to perform this measurement:

- Selecting a configuration in which the metallic loss is significant (fig. 2b). The shield must be approximately three times the resonator dimensions and the metal must be a good conductor (copper, silver, etc.).

  thus : $\tan \partial \approx \frac{\Delta f}{f}$ accuracy better than ± 10 % $Q = \frac{1}{\tan \partial}$

- Calculating the resonance fields and the currents induced in the metal wall. The metallic loss can be deduced from simple numerical methods or more complex numerical methods.

- Eliminating the metallic loss by the triple measurement method (permittivity of two resonators measured separately and together).

DIELECTRIC MATERIALS

Characterization

Temperature stability measurement

This typical measurement method is shown in Fig. 2a, using an automatic bench which permanently monitors the resonant frequency by modeling the transfer function of the resonator operating as a single-pole filter (Fig. 3).

Programmable climactic chamber

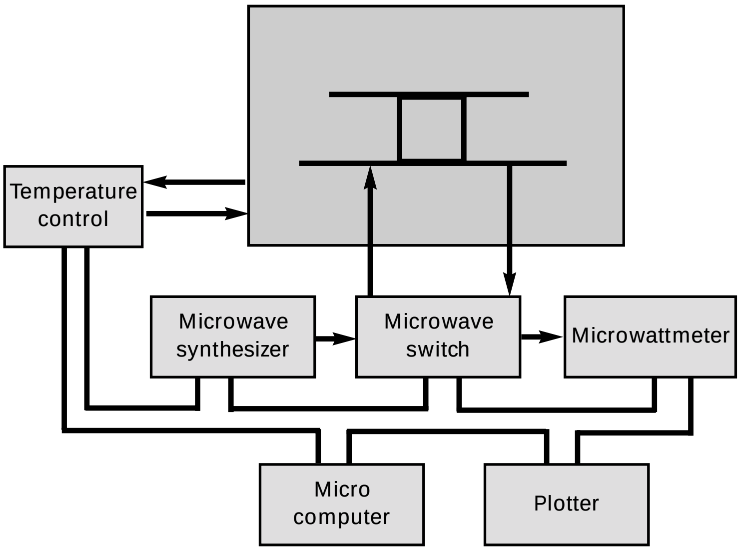


fig. 3
Measuring bench

USER GUIDE

Calculating frequency or dimensions

Several methods exist for calculating the resonant frequency of a resonator in a given environment: Eigen modes development, integration by finite elements, finite difference.

In practice, it is easier to use a simple formula:

$$F = \frac{233}{\sqrt{\varepsilon'}.V^{\frac{1}{3}}} \text{ GHz}$$

This formula can be used to give a preliminary determination (within 5 to 10 %) of the size for a given frequency. Using the measurement of this specified resonator, it is possible to determine the value of n.f.ϕ or n.f.$V^{1/3}$ in the considered environment and to correct one of the parameters while maintaining the product constant. Using this procedure, the correct result is rapidly obtained.

Dielectric resonators are available in the shape of disks, toroids and rods in accordance with the dimensions or frequency specified. The size ratio depends on the selected resonance mode and the customer application.

Frequency adjustment

Frequency correlation: as the resonant frequency is closely related to the DRO design, a frequency correlation between the user's test set and the TEMEX one has to be made according to the former sampling results. Our preferred solution is to get the test fixture of the customer. In case it is not possible, a duplication of the test jig we use can be provided.
The frequency adjustment can be achieved by several mechanical means:

- lapping the resonator, using diamond or silicon carbide tools, abrasive paste or paper,
- perturbing the fringing fields outside the dielectric resonator, via screws for example,
- using the so-called double resonator configuration, where two halves of the dielectric resonator act as one. With this method, a tuning range of up to 20 % can be achieved.

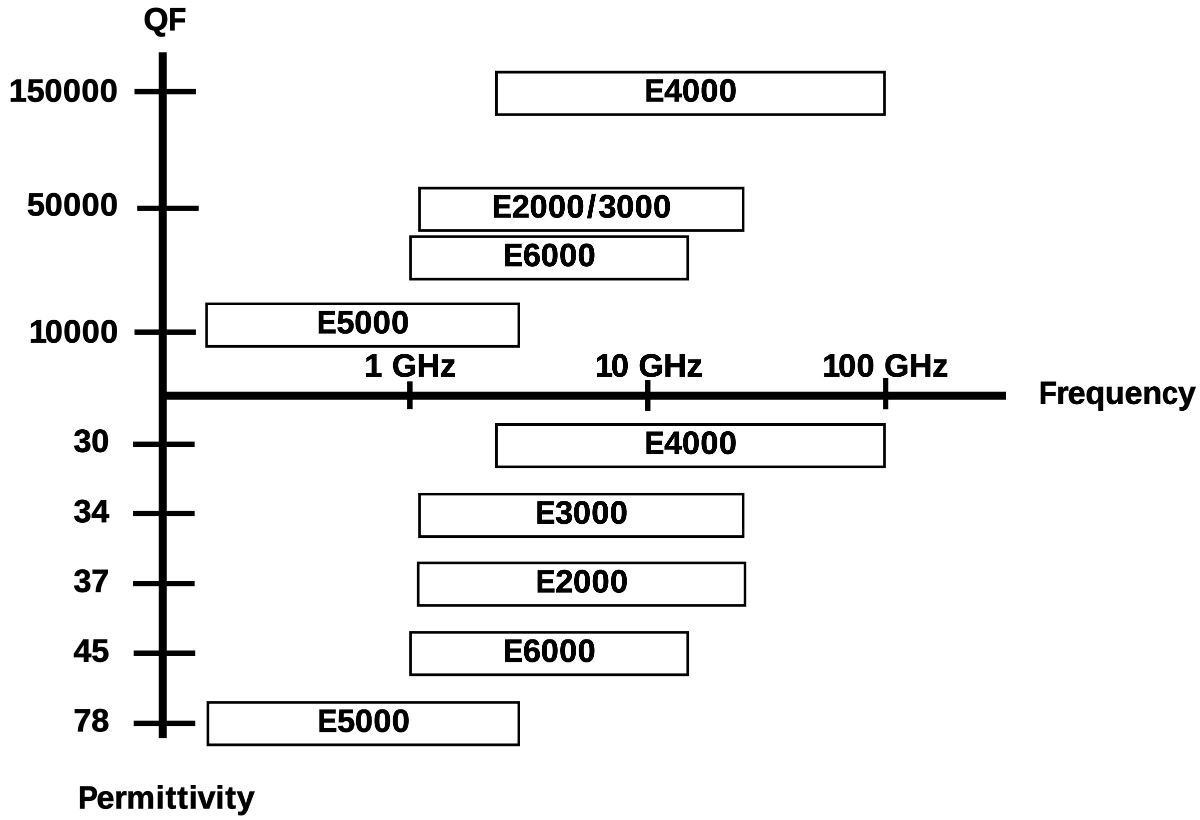
Coupling

In a microstrip circuit, the resonator is coupled by being located near a microstrip line. Basically, this is a magnetic coupling. Its value can be adjusted by varying either the distance between the resonator and the line or the height of the spacer between the resonator and the substrate. Common practice for achieving a higher overall Q factor is to use a spacer, which can be in alumina, silica or low polymer with low dielectric loss.

The resonator can overhang the line in order to provide as sufficient strong coupling. Note, however, that the coupling is cancelled when the resonator is centered on the line.

Loops or antennas can be used to provide the Input/Output coupling.

PRODUCT CHARACTERISTICS: GENERAL OVERVIEW



Electrical and physical characteristics

	E2000	E3000	E4000	E5000	E6000
Dielectric constant	37	34	30	78	45
Typical Q factor	5000 @ 10 GHz	4000 @ 10 GHz	15000 @ 10 GHz	1600 @ 5 GHz	8000 @ 5 GHz
Available tf (ppm/° C) (a)	-3 to 18	0 to 10	0 to 10	-3 to 9	-6 to 12
Non-linearity coefficient (b)	-35.10^{-9}	4.10^{-9}	-15.10^{-9}	30.10^{-9}	-35.10^{-9}
Recommended frequency range (GHz)	1.8 to 30	1.8 to 30	3 to 100	0.8 to 5	1 to 15
Thermal expansion (ppm/° C) (25° C)	6	5	10	8	6.5
Insulation resistivity (Ωm^{-1}) (25° C)	10^{15}	10^{15}	10^{15}	10^{14}	10^{15}
Thermal conductivity ($Wm^{-1}°K^{-1}$) (25° C)	2.1	1.7	2.5	2.9	2.1
Water absorption (%)	<0.01	<0.01	<0.01	<0.01	<0.01
Density	5.1	5.3	7.6	5.6	4.9

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DIELECTRIC MATERIALS

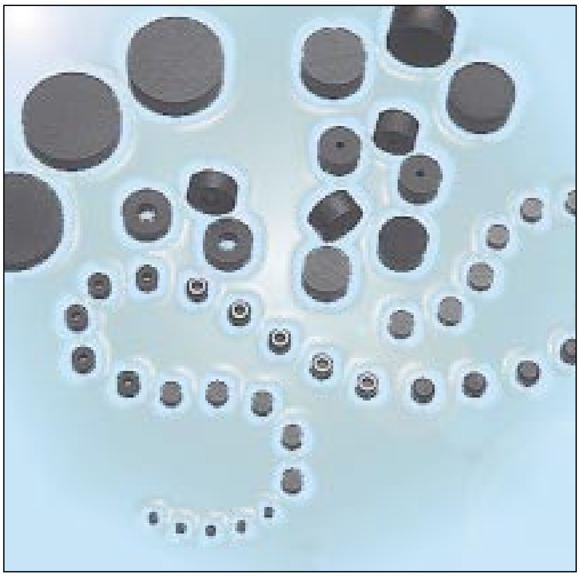
E2000 - General description

E2000 SERIES

Description

TEMEX has designed the E2000 series materials and a manufacturing process for applications which require:

- Mass production capacity
- A wide selection of temperature coefficients
- Tight frequency tolerances
- High Q factor for high stability DRO design
- High dielectric constant for size reduction
- Operating frequencies: 1.8 to 30 GHz



Q versus frequency curves available on request

Typical applications

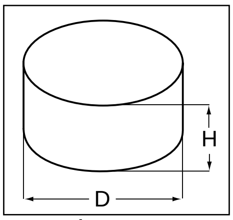
- Low Noise Block converters for D.B.S
- Security systems, detectors
- DRO for communication equipment
- Microwave filters
- Microwave sources

Ceramic characteristics

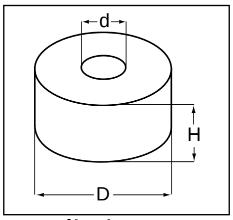
- Density: 5.2
- Composition: Zr Sn Ti Oxide
- Dielectric constant: 37.1 to 37.6
- Typical Q factor: 5000 @ 10 GHz

Standard characteristics

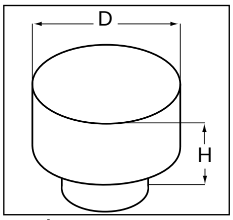
Typical configurations



Disc type



Cylinder type



Disc + support

DIELECTRIC MATERIALS

E2000 - Dimensions

TABLE 1: Dimensions and frequency, User guide

Part number	Standard diameter (D)		Frequency range (MHz)	
Disc type	mm	inches	F min.	F max
D020	2.00	0.079	26’800	32’200
D024	2.40	0.094	22’500	26’800
D027	2.70	0.106	20’000	22’500
D029	2.90	0.114	18’600	20’000
D034	3.40	0.134	15’800	18’600
D039	3.90	0.154	13’400	15’800
D046	4.60	0.181	10’900	13’400
D049	4.90	0.193	10’200	10’900
D053	5.30	0.209	9’800	10’200
D055	5.50	0.217	9’500	9’800
D057	5.70	0.224	9’100	9’500
D059	5.90	0.232	8’800	9’100
D065	6.50	0.256	8’000	8’800
D070	7.00	0.276	7’400	8’000
D076	7.60	0.299	6’800	7’400
D082	8.20	0.323	6’300	6’800
D088	8.80	0.346	5’900	6’300
D090	9.00	0.354	5’800	5’900
D103	10.30	0.406	5’000	5’800
D109	10.90	0.429	4’800	5’000
D114	11.40	0.449	4’500	4’800
D127	12.70	0.500	3’800	4’500
D145	14.50	0.571	3’400	3’800
D157	15.70	0.618	3’100	3’400
D175	17.50	0.689	2’800	3’100
D184	18.40	0.724	2’700	2’800
D200	20.00	0.787	2’500	2’700
D213	21.30	0.839	2’300	2’500
D234	23.40	0.921	2’100	2’300
D249	24.90	0.980	2’000	2’100
D260	26.00	1.024	1’900	2’000
D277	27.70	1.091	1’800	1’900
D294	29.40	1.157	1’700	1’800

Notes:
- Custom sizes are available on request.
- Substrates: rods can be delivered as well
- Diameter tolerance: ±0.10 mm as standard tolerance (±0.025 mm for specific production)
- Thickness: typical values, to be adjusted to get the required frequency

DIELECTRIC MATERIALS

E2000 - characteristics

TABLE 2: Main characteristics

Material	τf (ppm/° C)	Q factor (typical) @ 10 GHz	Dielectric constant ($\varepsilon \pm 0.5$)
E203N	-3	5 000	37.1
E200	0	5 000	37.2
E203	3	5 000	37.3
E206	6	5 000	37.4
E209	9	5 000	37.4
E212	12	5 000	37.6
E215	15	5 000	37.6
E218	18	5 000	37.6

Note:
- Other values are possible on request
- For substrate, dielectric constant is given with $\varepsilon \pm 1$

TABLE 3: Temperature coefficient (τf) tolerances

Tolerance type	Tolerance (ppm/° C)
T	± 2
U	± 1.5
V	± 1

TABLE 4: Frequency tolerance

Tolerance type	Frequency tolerance	AQL
A	± 1 %	1.5 %
B	± 0.5 %	1.5 %
C	Specify the freq. tolerance in MHz (± xx)	1.5 %

Note:
- Other frequency tolerance can be achieved according to a specific requirement.
- Each lot is controlled according to international norm MIL STD 414 Level 1 (available on request).

DIELECTRIC MATERIALS

E2000 - How to order?

How to order? (with frequency specification)

D	049	E212	T	10500	A
Part number Disc diameter	**Standard diameter** See table 1 (D x 10) in mm	**Material** See table 2	**Temperature coefficient (τf) tolerances** See table 3	**Frequency (MHz)**	**Frequency tolerance** See table 4

How to order? (with size specification)

D	057	E206	L	026	U
Part number Disc diameter	**Standard diameter** See table 1 (D x 10) in mm	**Material** See table 2	**Length**	**Thickness** (H x 10) in mm	**Temperature coefficient (τf) tolerances** See table 3

- **Marking**: optional marking is available on request. Several types of marking are possible. Please, ask your local Sales Office for further information.
- Tape and reel packaging possible if required (several formats available).
- Cylinder type available on request.

DIELECTRIC MATERIALS

E3000 - General description

E3000 SERIES

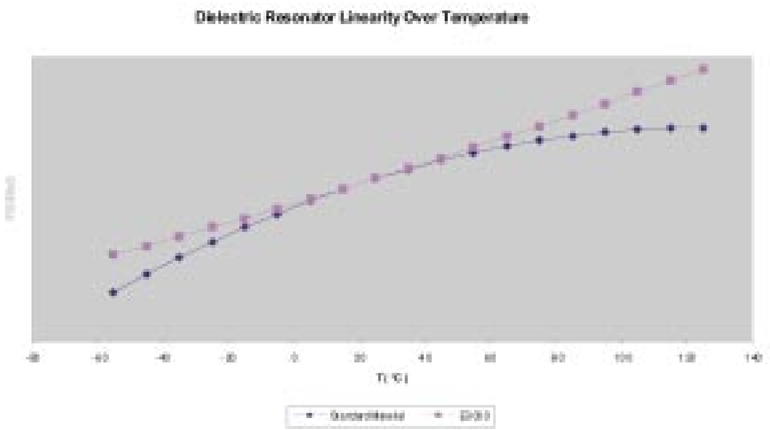
Description

TEMEX has designed the E3000 series material and a manufacturing process for applications which require:

- A wide selection of temperature coefficients,
- Tight frequency tolerances,
- High Q factor for high stability DRO design,
- High dielectric constant for size reduction,
- Operating frequencies: 1.8 to 30 GHz.

Q versus frequency curves available on request

The E3000 series was specifically designed for space applications where the requirements are very tough to meet. As shown in the chart here below, the second order parameter is gone and we are then facing a linear behavior among temperature. Thus resulting in a impressive stability all the whole system among temperature.

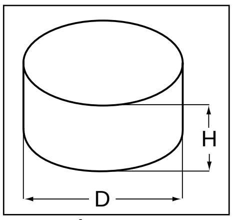


Typical applications

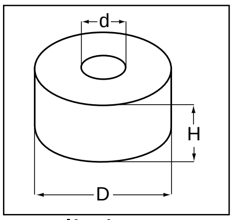
- Satellite multiplexing filter devices
- High stability DROs

Standard characteristics

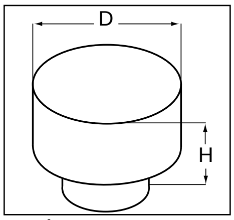
Typical configurations



Disc type



Cylinder type



Disc + support

TABLE 5: Dimensions and frequency, User guide

Part number	Standard diameter (D)		Frequency range (MHz)	
Disc type	mm	inches	F min.	F max
D020	2.00	0.079	28'000	33'500
D024	2.40	0.094	23'400	28'000
D027	2.70	0.106	20'900	23'400
D029	2.90	0.114	19'500	20'900
D034	3.40	0.134	16'500	19'500
D039	3.90	0.154	14'000	16'500
D046	4.60	0.181	11'300	14'000
D049	4.90	0.193	10'700	11'300
D053	5.30	0.209	10'300	10'700
D055	5.50	0.217	9'900	10'300
D057	5.70	0.224	9'500	9'900
D059	5.90	0.232	9'200	9'500
D065	6.50	0.256	8'300	9'200
D070	7.00	0.276	7'700	8'300
D076	7.60	0.299	7'100	7'700
D082	8.20	0.323	6'600	7'100
D088	8.80	0.346	6'200	6'600
D090	9.00	0.354	6'000	6'200
D103	10.30	0.406	5'200	6'000
D109	10.90	0.429	5'000	5'200
D114	11.40	0.449	4'700	5'000
D127	12.70	0.500	4'000	4'700
D145	14.50	0.571	3'500	4'000
D157	15.70	0.618	3'300	3'500
D175	17.50	0.689	3'000	3'300
D184	18.40	0.724	2'800	3'000
D200	20.00	0.787	2'600	2'800
D213	21.30	0.839	2'400	2'600
D234	23.40	0.921	2'200	2'400
D249	24.90	0.980	2'100	2'200
D260	26.00	1.024	2'000	2'100
D277	27.70	1.091	1'900	2'000
D294	29.40	1.157	1'800	1'900
D327	32.70	1.287	1'600	1'800

Notes:
- Custom sizes are available on request.
- Substrates: rods can be delivered as well
- Diameter tolerance: ±0.10 mm as standard tolerance (±0.025 mm for specific production)
- Thickness: typical values, to be adjusted to get the required frequency

DIELECTRIC MATERIALS

E3000 - Characteristics

TABLE 6: Main characteristics

Material	τf (ppm/° C)	Q factor (typical) @ 10 GHz	Dielectric constant (ε ± 0.5)
E300	0	4 000	34.0
E302	2	4 000	34.2
E304	4	4 000	34.4
E306	6	4 000	34.7
E308	8	4 000	35.0
E310	10	4 000	35.3

Note:
- Other values are possible on request
- For substrate, dielectric constant is given at ε ± 1

TABLE 7: Temperature coefficient (τf) tolerances

Tolerance type	Tolerance (ppm/° C)
T	± 2
U	± 1.5
V	± 1

TABLE 8: Frequency tolerance

Tolerance type	Frequency tolerance	AQL
A	± 1 %	1.5 %
B	± 0.5 %	1.5 %
C	Specify the freq. tolerance in MHz (± xx)	1.5 %

Note:
- Other frequency tolerance can be achieved according to a specific requirement.
- Each lot is controlled according to international norm MIL STD 414 Level 1 (available on request).

How to order?
(with frequency specification)

D	049	E300	U	11000	C050
Part number	**Standard diameter**	**Material**	**Temperature coefficient (τf) tolerances**	**Frequency (MHz)**	**Frequency tolerance**
Disc diameter	See table 5 (D x 10) (in mm)	See table 6	See table 7		See table 8

How to order?
(with size specification)

D	057	E306	L	026	V
Part number	**Standard diameter**	**Material**	**Length**	**Thickness**	**Temperature coefficient (τf) tolerances**
Disc diameter	See table 5 (D x 10) in mm	See table 6		(H x 10) in mm	See table 7

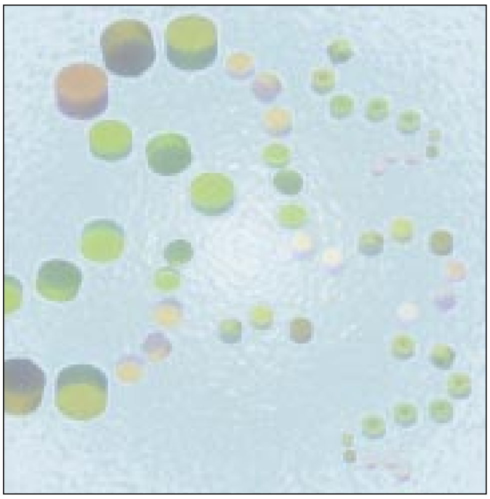
- **Marking**: optional marking is available on request. Several types of marking are possible. Please, ask your local Sales Office for further information.
- Tape and reel packaging possible if required (several formats available).
- Cylinder type available on request.

DIELECTRIC MATERIALS

E4000 - General description

E4000 SERIES

Description



TEMEX has designed a range of very high Q dielectric resonators operating in microwave and millimetric frequency range. This series offers a typical Q factor of 15000 at 10 GHz.

The E4000 series is especially suitable for applications which require:

- Low losses @ high-frequencies
- Temperature stability
- Low phase noise
- Tight bandwidth
- Operating frequencies: 3 GHz to 100 GHz

Q versus frequency curves available on request

Typical applications

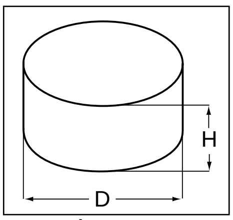
- High stability DROs
- Satellite multiplexing filters devices
- Millimetric applications:
  - Automotive anti-collision
  - Radar
  - Traffic control systems
- Millimeter waves radio-links for communications and data transmission (LMDS, MVDS)
- Millimeter waves alarm systems

Ceramic characteristics

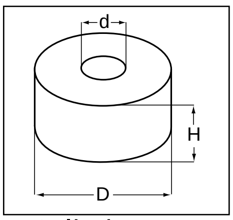
- Density: 7.6
- Chemical composition: Ba Zn Ta Oxide
- Dielectric constant: 29.5 to 32.0
- Typical Q factor: 15000 @ 10 GHz

Standard characteristics

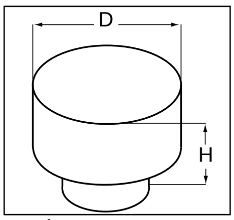
Typical configurations



Disc type



Cylinder type



Disc + support

DIELECTRIC MATERIALS

E4000 - Dimensions

TABLE 9: Dimensions and frequency, User guide

Part number	Standard diameter (D)		Frequency range (MHz)	
Disc type	mm	inches	F min.	F max
D011	1.10	0.043	30'900	43'000
D015	1.50	0.059	25'000	30'900
D033	3.30	0.130	14'200	25'000
D037	3.70	0.146	12'900	14'200
D044	4.40	0.173	10'600	12'900
D047	4.70	0.185	9'900	10'600
D050	5.00	0.197	9'500	9'900
D058	5.80	0.228	8'300	9'500
D061	6.10	0.240	8'000	8'300
D070	7.00	0.276	7'200	8'000
D072	7.20	0.283	7'000	7'200
D075	7.50	0.295	6'700	7'000
D083	8.30	0.327	6'100	6'700
D094	9.40	0.370	5'500	6'100
D100	10.00	0.394	5'200	5'500
D103	10.30	0.406	5'000	5'200
D105	10.50	0.413	4'900	5'000
D121	12.10	0.476	4'300	4'900
D138	13.80	0.543	3'800	4'300
D149	14.90	0.587	3'600	3'800
D166	16.60	0.654	3'200	3'600
D175	17.50	0.689	3'000	3'200
D190	19.00	0.748	2'800	3'000
D202	20.20	0.795	2'700	2'800

Notes:
- Other sizes are available on request
- Diameter tolerance: ±0.10 mm as standard tolerance (±0.025 mm for specific production)
- Thickness: typical values, to be adjusted to get the required frequency

DIELECTRIC MATERIALS

E4000 - Characteristics

TABLE 10: Main characteristics

Material	τf (ppm/° C)	Q factor (typical) @ 10 GHz	Dielectric constant (ε ± 1)
E400	0	15 000	29.5
E402	2	15 000	30.0
E404	4	15 000	30.5
E406	6	15 000	31.0
E408	8	15 000	31.5
E410	10	15 000	32.0

Note:
- Other values are possible on request
- For substrate, dielectric constant is given with ε ± 1

TABLE 11: Temperature coefficient (τf) tolerances

Tolerance type	Tolerance (ppm/° C)	Process
T	± 2	Mass production
U	± 1.5	Mass production
V	± 1	Mass production

TABLE 12: Frequency tolerance

Tolerance type	Frequency tolerance	AQL
A	± 1 %	1.5 %
B	± 0.5 %	1.5 %
C	Specify the freq. tolerance in MHz (± xx)	1.5 %

Note:
- Other frequency tolerance can be achieved according to a specific requirement.
- Each lot is controlled according to international norm MIL STD 414 Level 1 (available on request).

DIELECTRIC MATERIALS

E4000 - How to order?

How to order?
(with frequency specification)

D	047	E404	V	10200	A
Part number Disc diameter	**Standard diameter** See table 9 (D x 10) (in mm)	**Material** See table 10	**Temperature coefficient (τf) tolerances** See table 11	**Frequency (MHz)**	**Frequency tolerance** See table 12

How to order?
(with size specification)

D	058	E406	L	026	T
Part number Disc diameter	**Standard diameter** See table 9 (D x 10) in mm	**Material** See table 10	**Length**	**Thickness** (H x 10)	**Temperature coefficient (τf) tolerances** See table 11

- **Marking**: optional marking is available on request. Several types of marking are possible. Please, ask your local Sales Office for further information.
- Tape and reel packaging possible if required (several formats available).
- Cylinder type available on request.

DIELECTRIC MATERIALS
E5000 - General description

E5000 SERIES

Description

TEMEX has designed a range of dielectric resonators exhibiting a very high dielectric constant, especially designed for lower frequency applications.

This material has been especially designed for applications which require:

- Reduced dimensions
- Lower height
- Temperature stability
- Operating frequencies from 0.8 to 5 GHz

Q versus frequency curves available on request

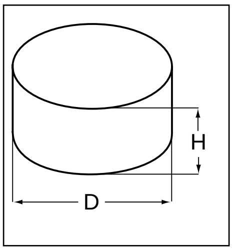
Typical applications

- Computer networks (WLAN, Bluetooth)
- Duplexers, Filters
- Cellular base stations (GSM, PCN, PCS)

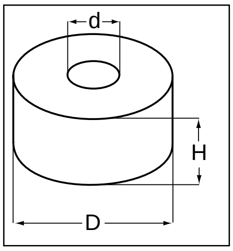
Ceramic characteristics

- Density: 5.6
- Chemical composition: Ba Sm Ti Oxide
- Dielectric constant: 77.8 to 78.6
- Typical Q factor: 1600 @ 5 GHz

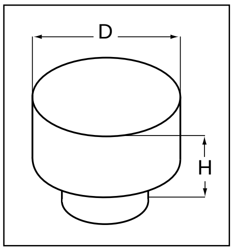
Typical configurations



Disc type



Cylinder type



Disc + support

DIELECTRIC MATERIALS

E5000 - Dimensions

TABLE 13: Dimensions and frequency, User guide

Part number	Standard diameter (D)		Frequency range (MHz)	
Disc type	mm	inches	F min.	F max
D076	7.60	0.299	4'800	5'700
D083	8.30	0.327	4'400	4'800
D089	8.90	0.350	4'100	4'400
D090	9.00	0.354	4'000	4'100
D101	10.10	0.398	3'600	4'000
D103	10.30	0.406	3'500	3'600
D109	10.90	0.429	3'300	3'500
D115	11.50	0.453	3'100	3'300
D128	12.80	0.504	2'600	3'100
D146	14.60	0.575	2'300	2'600
D158	15.80	0.622	2'200	2'300
D176	17.60	0.693	1'900	2'200
D186	18.60	0.732	1'800	1'900
D202	20.20	0.795	1'700	1'800
D215	21.50	0.846	1'600	1'700
D236	23.60	0.929	1'500	1'600
D250	25.00	0.984	1'400	1'500
D262	26.20	1.031	1'300	1'400
D280	28.00	1.102	1'200	1'300
D330	33.00	1.299	1'100	1'200
D346	34.60	1.362	1'000	1'100
D368	36.80	1.449	900	1'000
D458	45.80	1.803	800	900
D518	51.80	2.039	700	800

Notes:
- Other sizes are available on request
- Diameter tolerance: ±0.10 mm as standard tolerance (±0.025 mm for specific production)
- Thickness: typical values, to be adjusted to get the required frequency

TABLE 14: Main characteristics

Material	τf (ppm/° C) (±2.0)	Q factor (typical) @ 5 GHz	Dielectric constant ($\varepsilon \pm 2$)
E503N	-3	1 600	77.8
E500	0	1 600	78.0
E503	3	1 600	78.2
E506	6	1 600	78.4
E509	9	1 600	78.6

Notes:
- Other sizes are available on request
- Diameter tolerance: ±0.10 mm as standard tolerance (±0.025 mm for specific production)
- Thickness: typical values, to be adjusted to get the required frequency

DIELECTRIC MATERIALS

E5000 - Dimensions

TABLE 15: Temperature coefficient (τf) tolerances

Tolerance type	Tolerance (ppm/° C)
T	± 2
U	± 1.5
V	± 1

TABLE 16: Frequency tolerance

Tolerance type	Frequency tolerance	AQL
A	± 1 %	1.5 %
B	± 0.5 %	1.5 %
C	Specify the freq. tolerance in MHz (± xx)	1.5 %

Note:
- Other frequency tolerance can be achieved according to a specific requirement.
- Each lot is controlled according to international norm MIL STD 414 Level 1 (available on request).

How to order? (with frequency specification)

D	083	E500	T	4600	C040
Part number Disc diameter	**Standard diameter** See table 13 (D x 10) (in mm)	**Material** See table 14	**Temperature coefficient (τf) tolerances** See table 15	**Frequency (MHz)**	**Frequency tolerance** See table 16

How to order? (with size specification)

D	109	E500	L	049	U
Part number Disc diameter	**Standard diameter** See table 13 (D x 10) in mm	**Material** See table 14	**Length**	**Thickness** (H x 10) in mm	**Temperature coefficient (τf) tolerances** See table 15

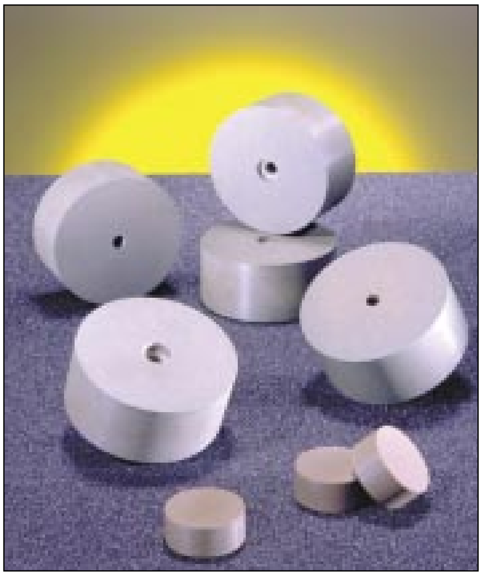
- **Marking**: optional marking is available on request. Several types of marking are possible. Please, ask your local Sales Office for further information.
- Tape and reel packaging possible if required (several formats available).
- Cylinder type available on request.

E6000 SERIES

Description

TEMEX has designed the E6000 series material and a manufacturing process for applications which require:

- A wide selection of temperature coefficients,
- Tight frequency tolerances,
- High Q factor for high stability DRO design,
- High dielectric constant for size reduction,
- Operating frequencies: 1 to 15 GHz.



Q versus frequency curves available on request

Typical applications

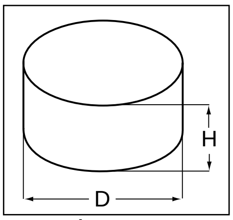
- Low Noise Block converters for D.B.S
- Security systems, detectors
- DRO for communication equipment
- Microwave filters
- Microwave sources

Ceramic characteristics

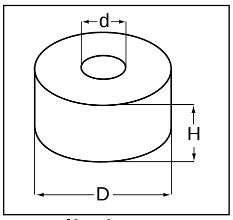
- Density: 4.90
- Composition: Ti Zr Nb Zn Oxide
- Dielectric constant: 43.9 to 46.0
- Typical Q factor: 8000 @ 5 GHz

Standard characteristics

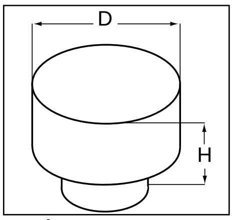
Typical configurations



Disc type



Cylinder type



Disc + support

DIELECTRIC MATERIALS

E6000 - Dimensions

TABLE 17: Dimensions and frequency, User guide

Part number	Standard diameter (D)		Frequency range (MHz)	
Disc type	mm	inches	F min.	F max
D038	3.80	0.150	12’100	15’000
D045	4.50	0.177	10’200	12’100
D048	4.80	0.189	9’500	10’200
D052	5.20	0.205	8’800	9’500
D054	5.40	0.213	8’500	8’800
D057	5.70	0.224	8’000	8’500
D059	5.90	0.232	7’800	8’000
D064	6.40	0.252	7’300	7’800
D069	6.90	0.272	6’800	7’300
D075	7.50	0.295	6’200	6’800
D081	8.10	0.319	5’800	6’200
D087	8.70	0.343	5’400	5’800
D088	8.80	0.346	5’300	5’400
D101	10.10	0.398	4’600	5’300
D107	10.70	0.421	4’400	4’600
D113	11.30	0.445	4’100	4’400
D137	13.70	0.539	3’700	4’100
D143	14.30	0.563	3’300	3’700
D155	15.50	0.610	3’000	3’300
D172	17.20	0.677	2’700	3’000
D182	18.20	0.717	2’600	2’700
D197	19.70	0.776	2’400	2’600
D210	20.90	0.827	2’200	2’400
D231	23.10	0.909	2’000	2’200
D245	24.30	0.965	1’900	2’000
D256	25.70	1.008	1’800	1’900
D274	27.40	1.079	1’700	1’800
D289	28.90	1.138	1’600	1’700
D323	32.30	1.272	1’500	1’600
D339	33.90	1.335	1’400	1’500
D361	36.10	1.421	1’300	1’400
D449	44.90	1.768	1’000	1’300
D507	50.70	1.996	900	1’000

Notes:
- Other sizes are available on request
- Diameter tolerance: ±0.10 mm as standard tolerance (±0.025 mm for specific production)
- Thickness: typical values, to be adjusted to get the required frequency

DIELECTRIC MATERIALS

E6000 - characteristics

TABLE 18: Main characteristics

Material	τf (ppm/° C)	Q factor (typical) @ 5 GHz	Dielectric constant (ε ± 1)
E606N	-6	8 000	43.9
E603N	-3	8 000	44.3
E600	0	8 000	44.5
E603	3	8 000	45.0
E606	6	8 000	45.3
E609	9	8 000	45.5
E612	12	8 000	46.0

Note:
- other values are possible on request
- For substrate, dielectric constant is given at ε ± 1

TABLE 19: Temperature coefficient (τf) tolerances

Tolerance type	Tolerance (ppm/° C)
T	± 2
U	± 1.5
V	± 1

TABLE 20: Frequency tolerance

Tolerance type	Frequency tolerance	AQL
A	± 1 %	1.5 %
B	± 0.5 %	1.5 %
C	Specify the freq. tolerance in MHz (± xx)	1.5 %

Note:
- Other frequency tolerance can be achieved according to a specific requirement.
- Each lot is controlled according to international norm MIL STD 414 Level 1 (available on request).

DIELECTRIC MATERIALS

E6000 - How to order?

How to order?
(with frequency specification)

D	048	E600	U	10000	A
Part number Disc diameter	**Standard diameter** See table 17 (D x 10) in mm	**Material** See table 18	**Temperature coefficient (τf) tolerances** See Table 19	**Frequency (MHz)**	**Frequency tolerance** See table 20

How to order?
(with size specification)

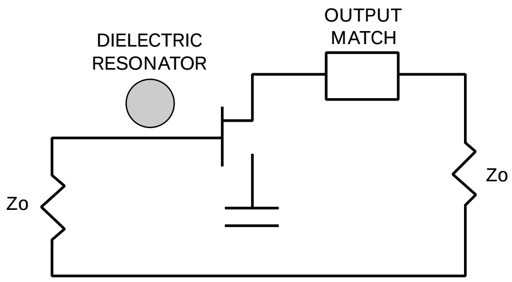
D	087	E600	L	039	V
Part number Disc diameter	**Standard diameter** See table 17 (D x 10) in mm	**Material** See table 18	**Length**	**Thickness** (H x 10) in mm	**Temperature coefficient (τf) tolerances** See table 19

- **Marking**: optional marking is available on request. Several types of marking are possible. Please, ask your local Sales Office for further information.
- Tape and reel packaging possible if required (several formats available).
- Cylinder type available on request.

TECHNICAL NOTES

OSCILLATORS

Microwave oscillators form an important part of all microwave systems such as those used in radar, communication links, navigation and electronic warfare (EW). With the rapid advancement of technology, there were an increasing need for better performance of oscillators. The emphasis has been on low noise, small size, low cost high efficiency, high temperature stability and reliability. The transistor dielectric resonator oscillator (TDRO) presents an interesting solution as a quality oscillator for fixed frequency or narrow-band tunable oscillators.

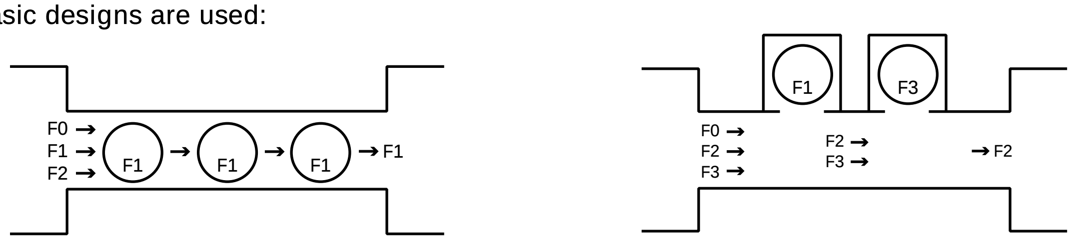


With the advent of temperature stable materials, the dielectric resonators has emerged as a high Q, low loss and conveniently sized element for applications in various microwave integrated circuits (MICs) for the entire microwave frequency range.

FILTERS

Filters use basic resonator principle: fields inside a resonator store energy at the resonant frequency where equal storage of electric and magnetic energies occurs.

Two basic designs are used:



Band-pass filter (serial coupling) **Band-stop filter (parallel coupling)**

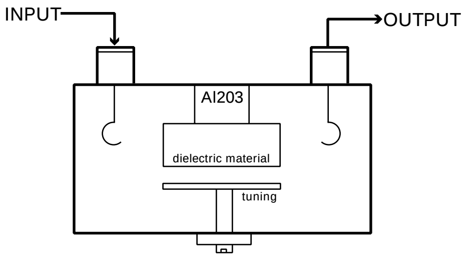
Band-pass filter: at the input (left side), signal consists of mixed frequencies. Each resonator has the same resonant frequency, so only this frequency F1 is allowed to pass from one resonator to the next and so on to the output (right side). Then, at the output, we are left with only F1.

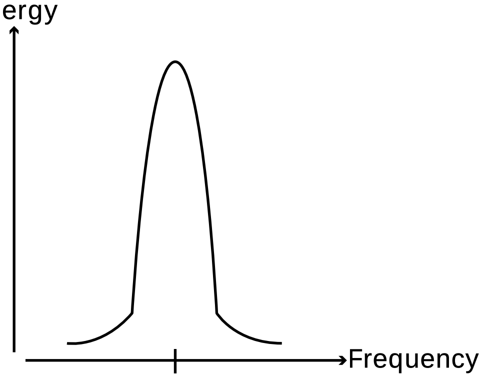
Band-stop filter: at the input (left side), signal is made up of mixed frequencies. Each resonator has a different resonant frequency, so only frequencies which differ from the resonant ones are transmitted to the output (right side). Then, at the output, we are left with all the frequencies from the input signal except for F1 and F32.

The following is an example of a band-pass filter: energy is transmitted from input to output via a dielectric resonator, so only the resonant frequency Fo remains at the output. Resonant frequency Fo may be adjusted by using a tuning metallic element.

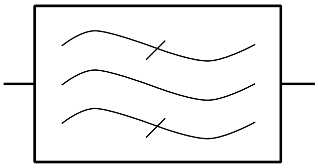
DIELECTRIC MATERIALS

Technical notes

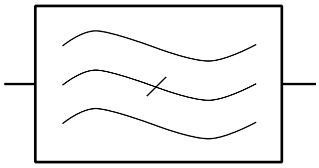




Symbols used to represent these filter functions are the following:



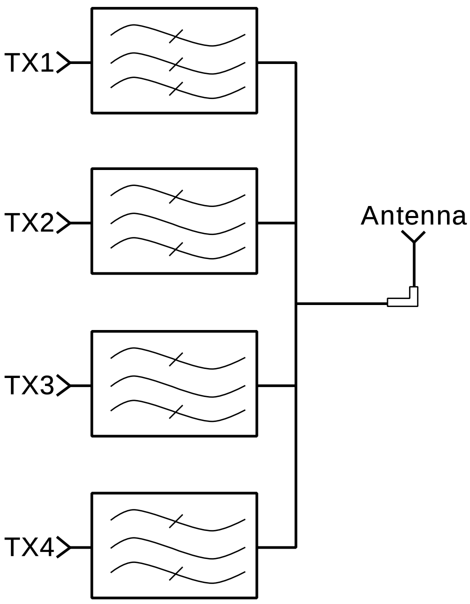
Band-pass filter
(selected frequency range is transmitted)



Band-stop filter
(selected frequency range is stopped)

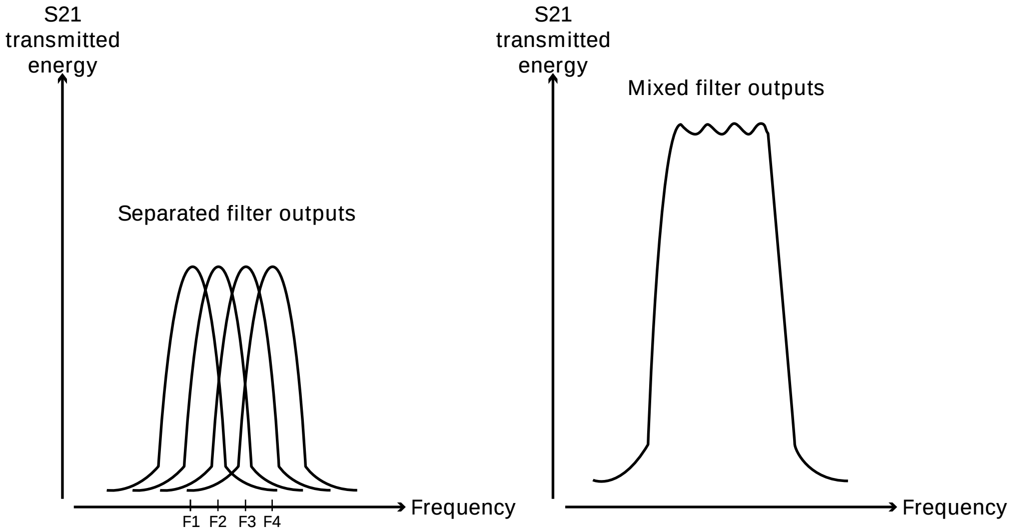
COMBINERS

Combiners are used to transmit multiple frequencies on a single antenna. In the case of a mobile phone base-station for example, they allow the handling of an increased number of frequency channels, and so increase the number of mobile phones (and people) connected. Combiners mainly use band-pass filters; the equivalent circuit is given below:

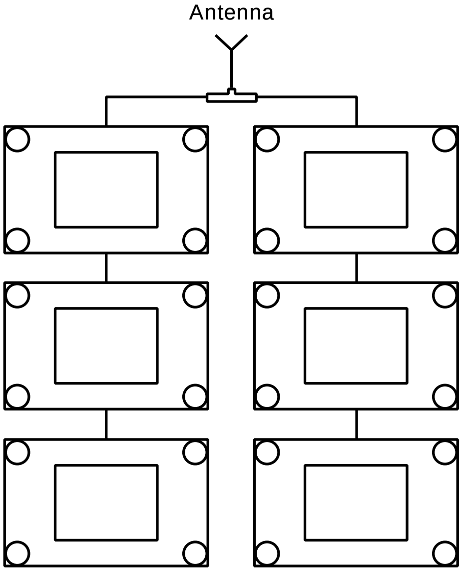


DIELECTRIC MATERIALS
Technical notes

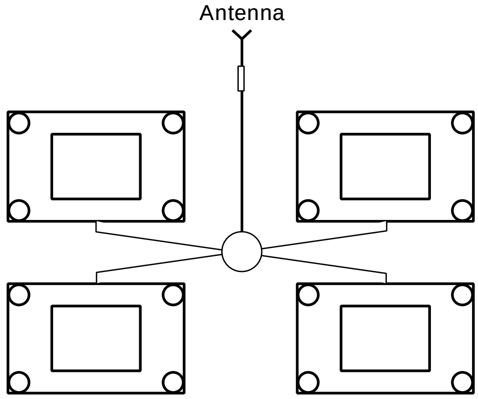
Each filter is centered on a particular frequency (dielectric resonator resonant frequency). The combiner output is obtained by the combining of several filter outputs. As shown in the next drawing, the increased bandwidth results in more channels being available.



Many configurations are available in order to expand the number of available channels:



24-channel system with six 4-channel combiner modules (serial phasing)



16-channel system with four 4-channel combiner modules (star phasing)

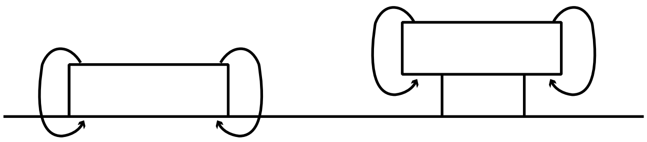
DIELECTRIC MATERIALS

Technical notes

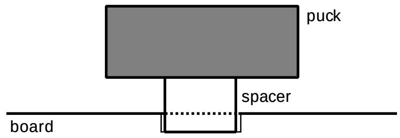
SPACER / STAND-OFF DESIGNS

In some specific designs, customers might require a spacer to be glued to our dielectric resonator. Purpose of this ceramic component is to:

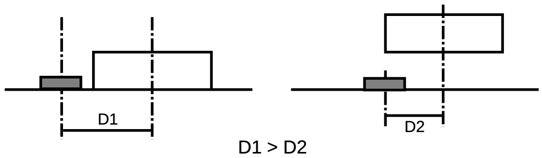
- either to improve the performances,



- or to help centering the resonator on the board,

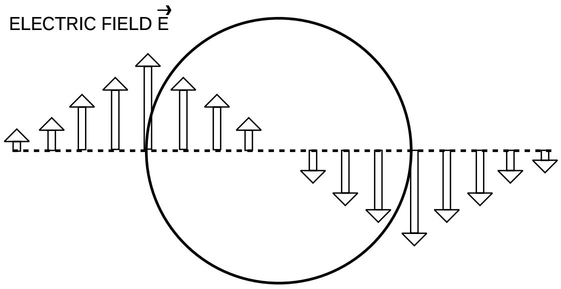


- or to increase the coupling factor, i.e. the Q factor also.



IMPROVING PERFORMANCES

Electric field, which is providing the "power" to the oscillator, is maximum at the circumference of the resonator. Therefore, if you can avoid any contact between the substrate and the periphery of the resonator, you minimize the losses.



A standoff pill is excellent in this case as the circumference of the resonator does not touch either the substrate or even the spacer. But you have to make a compromise because when you move away the puck from the line, coupling is decreasing and then less power is transmitted...

Also, the standoff allows the puck to be move away from the metallic surface (ground) below the substrate. Of course this will decrease the losses by preventing the magnetic field lines to escape using this short circuit.