DIELECTRIC RESONATORS

Operating frequencies in wireless communications have shifted towards high frequency band, and thus frequencies higher than 1 GHz are now commonly utilized. In addition, the microwave frequency spectrum becoming severely crowded and sub-divided into many different frequency bands, designers are systematically looking for resonators giving them a narrow bandwidth with smaller size. But selecting the right dielectric material for a given microwave application is a difficult challenge.

Temex Ceramics, being one of only a few manufacturers producing its own raw materials, is definitely the right partner to support designers at the early stage of development.

This also enables us to be independent from outside sources and flexible enough to rapidly adapt technologies to the changing needs of the market.

I. Basic Properties

Dielectric resonators are designed to replace resonant cavities in microwave functions such as filters and oscillators. The use of dielectric resonator inside these functions allows designers to get at low cost more compact devices with higher Q factor and temperature stability.

Dielectric resonators are generally fully “customized” and dedicated to very specific applications requiring Temex Ceramics early involvement in the design. The choice of the appropriate structure depends on various parameters which are listed below.

Resonance effect origins

The most commonly used mode in many applications is the $TE_{01\delta}$ (Transverse Electric Field).
Dielectric resonator traps microwave energy in an extremely small band of frequencies within the confines of the resonator volume. This energy is reflected back into the resonator due to the big gap in permittivity at the boundary of the resonator (air with $\varepsilon = 1$).

Nevertheless, a small part of this energy is distributed in the air around the resonator. These leakage magnetic fields do extend beyond the resonator structure and then can be used to provide coupling or adjusting the frequency with a loop or a stripline (Figure 1).

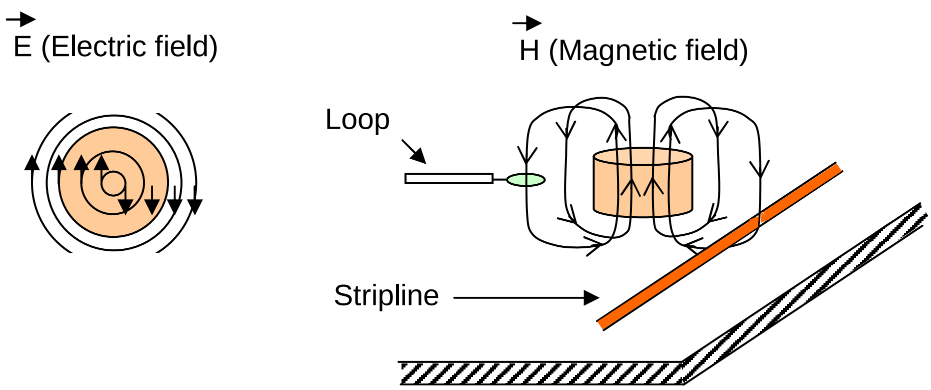


Figure 1

DIELECTRIC RESONATORS

Resonant frequency: f

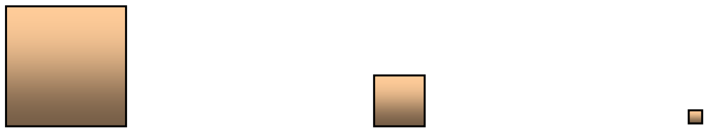
An isolated dielectric resonator is characterized by its resonant frequency which corresponds to a minimum of dielectric losses. This frequency f is primarily determined by the material dielectric constant (ε_r) and the volume V (mm^3) of the resonator and can be approximated by:

$$f \approx \frac{233}{\sqrt{\varepsilon_r} \cdot V^{1/3}}$$

This formula can be used to give a preliminary determination (within 5 to 10%) of the size. Nevertheless, it is worth to point that a frequency correlation between the customer's test jig and the Temex Ceramics one has to be made according to the former sampling results.

Dielectric constant: ε_r

The key reason for choosing a dielectric resonator is the size reduction afforded by a high ε_r compared to a cavity air filter. It indeed appears according to the above formula, that the dielectric constant determines the resonator dimension at a given frequency. The higher the dielectric constant, the smaller the space within which the fields are concentrated, the lower the dimension at a defined frequency.



Air (ε_r = 1) E2000 (ε_r = 37) E5000 (ε_r = 78)

Quality Factor: Q

The Q value of a dielectric resonator is the ratio between the energy stored within the resonator to the energy dissipated in the air per cycle. It defines the losses in the material which are represented by :

$$tg(\delta) = \frac{\varepsilon''}{\varepsilon'}$$

where δ is the loss angle, ε' the dielectric constant and ε'' the dielectric losses.

The Q factor equals to: $$Q = \frac{1}{tg(\delta)} = \frac{\varepsilon'}{\varepsilon''}$$

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, also specified by Q x f where f is the measurement frequency.

Typical values for E4000 family: Q = 15 000, f = 10 GHz } Q x f = 150 000 GHz

Temperature coefficient: τ_f

The resultant frequency of a microwave system typically decreases as temperature increases. This system is then said having a negative temperature coefficient. But usually, a system is required to be stable with temperature in the whole operating range of temperature (-55℃/+125℃ for example). Then this frequency shift with temperature can be compensated using a dielectric resonator with a positive temperature coefficient.

The temperature coefficient of a resonator is defined by:

$$\tau_f = \frac{\Delta f}{f} \bullet \frac{1}{\Delta T}$$

where f is the resonant frequency (MHz) at ambient temperature, Δf the frequency variation (MHz) among the ΔT temperature range (℃).

II. User Guide

How to order

Example for dielectric resonator in dimension: E2036 C 11.00x4.00x5.35

E2036	C	11.00	x	4.00	x	5.35
Material See our dielectric families	**Shape** D : Disk S : Square C : Cylinder	**Dimension 1** Diameter for D Length 1 for S Outer diameter for C		**Dimension 2** Length 2 for S Inner diameter for C		**Dimension 3** Thickness for D Thickness for S Thickness for C

Example for dielectric resonator in frequency: E2036 C 11.00x4.00 F5000+/-50

E2036	C	11.00	x	4.00	F5000	+/-	50
Material See our dielectric families	**Shape** D : Disk C : Cylinder	**Dimension 1** Diameter for D Diameter ext for C		**Dimension 2** Inner diameter for C	**Frequency**		**Tolerance in frequency** 1% or 0.5% (ask for others)

Example for dielectric resonator with spacer in dimension: E2036/AL C 11.00x4.00x5.35

E2036	/	AL	C	11.00	x	4.00	x	5.35
Material See our dielectric families		**Spacer** In AL2O3	**Shape** D : Disk S : Square C : Cylinder	**Dimension 1** Diameter for D Length 1 for S Outer diameter for C		**Dimension 2** Length 2 for S Inner diameter for C		**Dimension 3** Thickness for D Thickness for S Thickness for C

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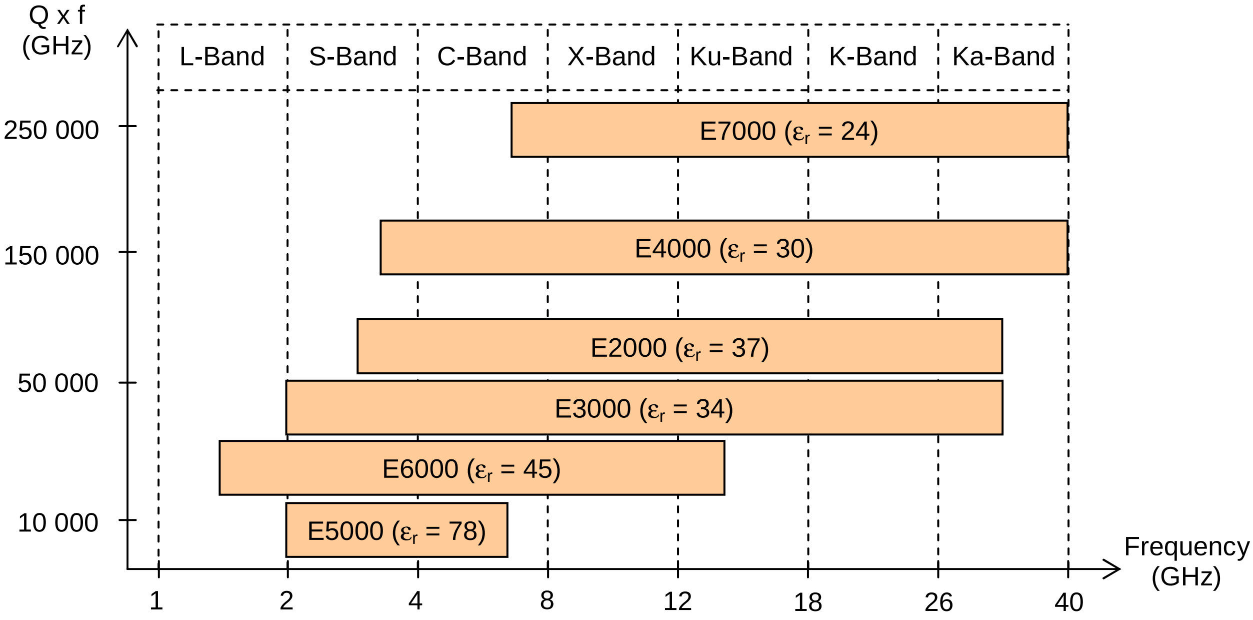
DIELECTRIC RESONATORS

Materials and applications

Dielectric resonator applications are wide and the right material choice has to be done taking into account the size and Q factor requirements. Below figures and tables are useful to identify the right candidates. The frequency range from 1.5 up to 40 GHz is covered through different materials.

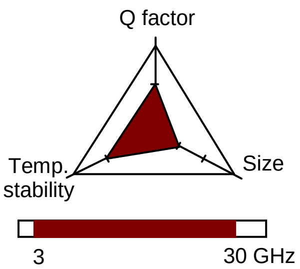


	PROPERTIES	APPLICATIONS
E2000 serie	High Q factor for high stability DRO designs. Mass-production capacity	- Alarm-detection systems, door openers - Anti-collision radar for automotive - Communication equipments - Low Noise Block (LNB) converters for DBS
E3000 serie	High linearity of frequency with temperature	- DRO for military and space applications
E4000 serie	Very high Q factor for filter designs	- Satellite multiplexing filter devices - Radio-links for communication systems (LMDS) - Anti-collision radar for automotive - Military radars
E5000 serie	High dielectric constant for reduced dimension systems	- Duplexers, filters - Cellular base stations
E6000 serie	High Q factor for low frequency applications	- Low Noise Block (LNB) converters for DBS - Security systems, detectors - Filters
E7000 serie	Ultra High Q factor for filter designs	- Satellite multiplexing filter devices - Radio-links for communication systems (LMDS) - Military radars

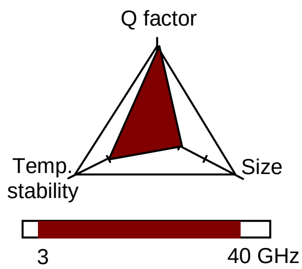
DIELECTRIC RESONATORS

Electrical and physical characteristics are listed in below table.

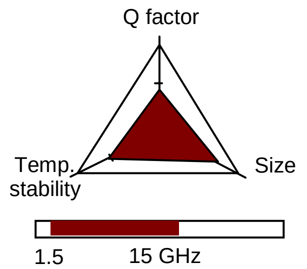
	E2000	E3000	E4000	E5000	E6000	E7000
Dielectric constant	37	34	30	78	45	24
Typical Q factor	5000 @ 10 GHz	4000 @ 10 GHz	15000 @ 10 GHz	1600 @ 5 GHz	8000 @ 5 GHz	25000 @ 10 GHz
Recommended frequency range (GHz)	3 to 30	2 to 30	3 to 40	2 to 5	1.5 to 15	10 to 24
Available τ_f (ppm/℃)	0 to 15	0 to 10	0 to 10	0	-6 to 12	0 to 6
Thermal expansion (ppm/℃)	6	5	10	8	6.5	10
Insulation resistivity (Ωm^{-1}) (25℃)	10^{15}	10^{15}	10^{15}	10^{14}	10^{15}	10^{15}
Thermal conductivity ($Wm^{-1}K^{-1}$) (25℃)	2.1	1.7	2.5	2.9	2.1	3.2
Water absorption (%)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Density	5.2	5.3	7.6	5.6	4.9	7.5
Oxide composition	Zr Sn Ti	Zr Sn Ti	Ba Zn Ta	Ba Sm Ti	Ti Zr Nb Zn	Ba Mg Ta



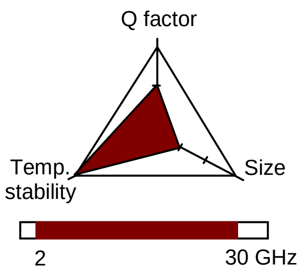
E2000



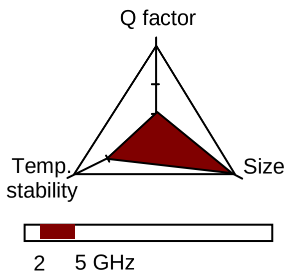
E4000



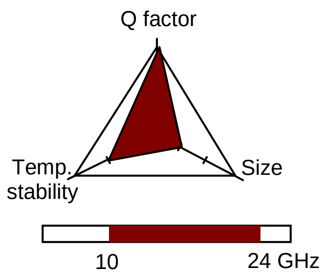
E6000



E3000



E5000

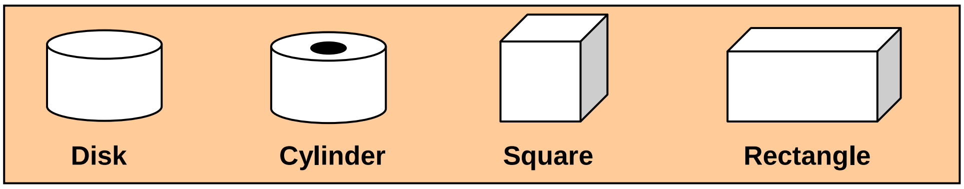


E7000

DIELECTRIC RESONATORS

Shape and metallization

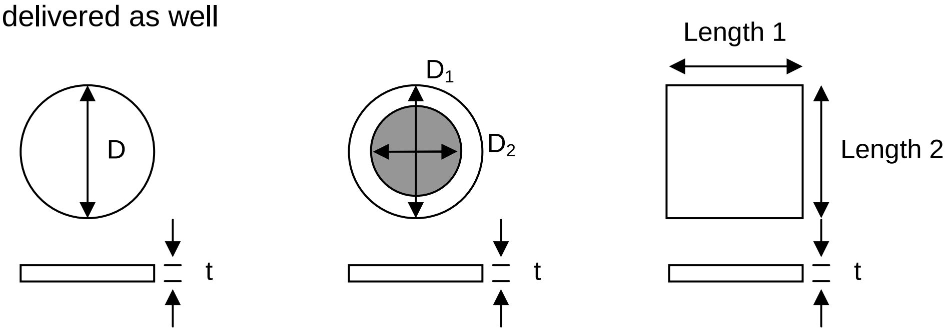
Various shapes and metallization are available (custom shape on request).



Dimensioning

A wide range of dimensions can be made based on customer specifications:
Disk: diameter 1 up to 55 mm (typical value)
Cylinder: diameter 1 up to 55 mm (typical value)
Square / Rectangle: max length 50.8 x 50.8 mm / Thickness 0.5 mm up to 3 mm (typical value)

Remarks:
- Standard tolerances are +/-0.05 mm on both diameter and thickness.
- As-fired parts (no machining requested => lower cost) are available for +/-1% tolerance.
- Smaller tolerances can be considered on request.
- Rods can be delivered as well



Spacer:

In some specific designs, customers might require spacers.

In filters, there are metal sidewalls and the dielectric resonator is usually placed on the bottom of the cavity, directly on the metal. This one is then dependent upon not just the ceramic, but also on its surroundings. The nominal frequency as well as the Q factor, are then affected. A common practice for achieving a higher Q factor is to glue a spacer with low dielectric loss (made of Alumina AL2O3) to our dielectric resonator. Thus magnetic fields are taken away from the metal wall (Figure 1).

In a microstrip circuit, the resonator is coupled by being located near a microstrip line. This magnetic coupling is adjusted by varying the distance between the resonator and the line. A better coupling can be achieved by adding a spacer so that the resonator can overhang the line (Figure 2).

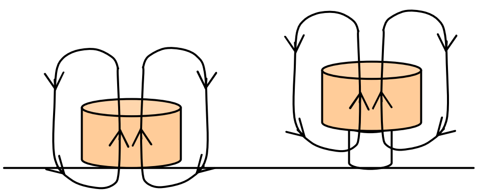


Figure 1

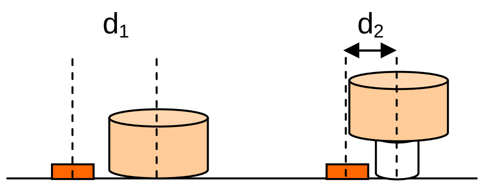
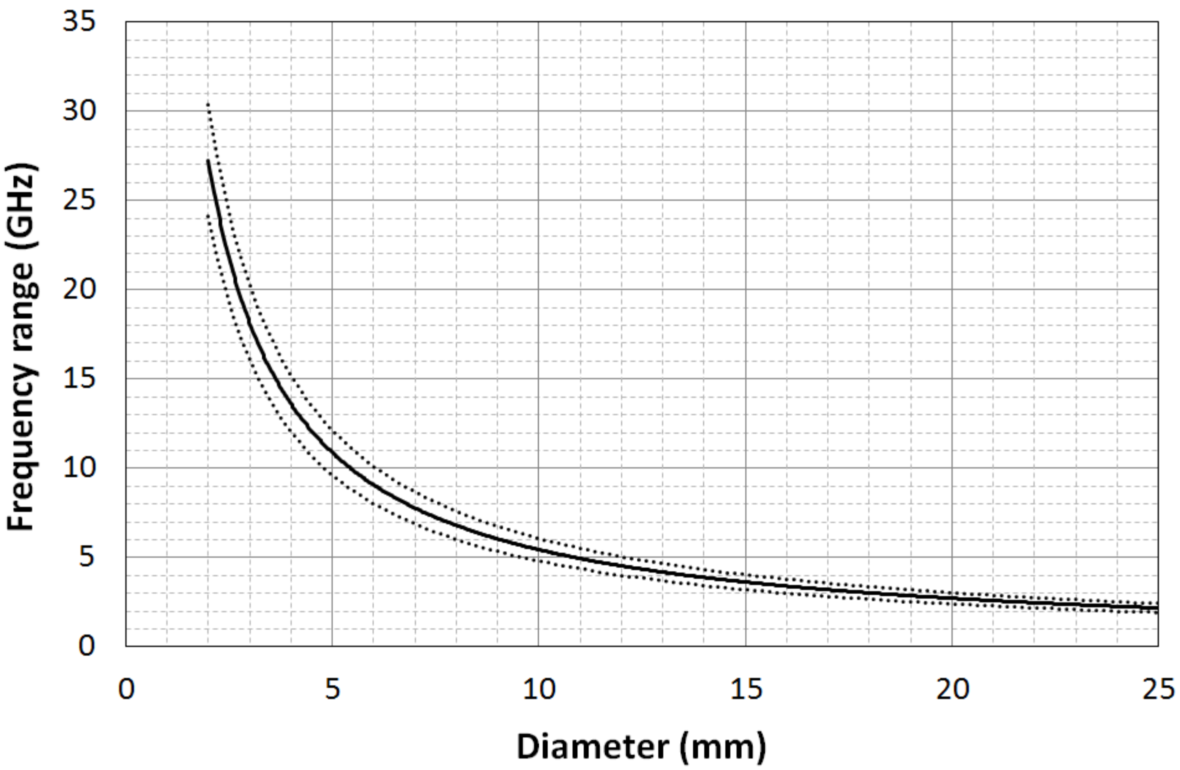


Figure 2

DIELECTRIC RESONATORS

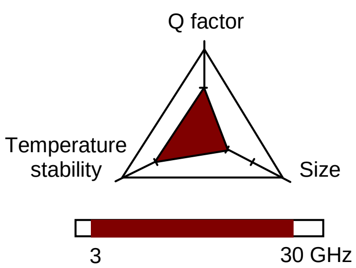
III. Dielectric materials

E2000 SERIE



Frequency (MHz)	Diameter range (mm)		
$1930 \leq F \leq 30350$	$D_{min} = \frac{48200}{F}$	$D_{typ} = \frac{54400}{F}$	$D_{max} = \frac{60700}{F}$
	$2 \leq D \leq 25$		

Notes: Custom sizes available on request

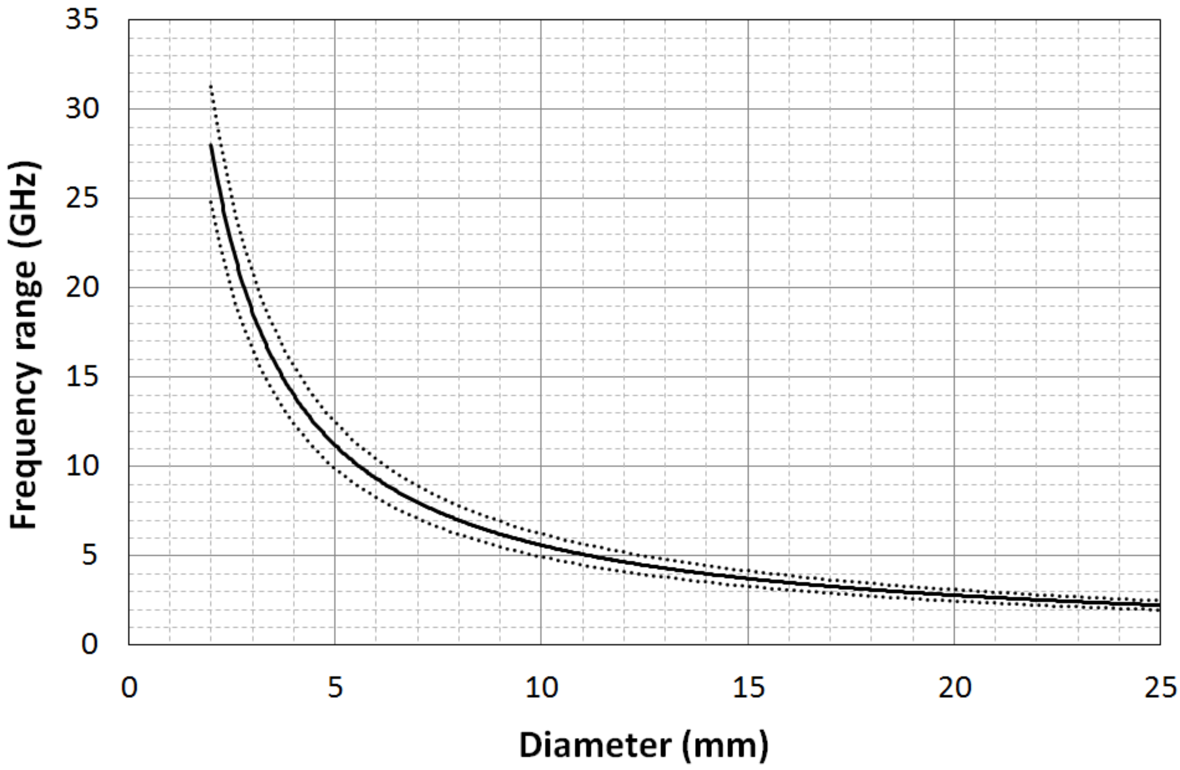


Material	τ_f (ppm/℃) +/-2ppm/℃	Typical Q factor @ 10GHz	Dielectric Constant ε_r +/-1
E2336N	-3	5 000	37.1
E2036	0	5 000	37.2
E2336	+3	5 000	37.3
E2636	+6	5 000	37.4
E2936	+9	5 000	37.4
E21236	+12	5 000	37.6
E21536	+15	5 000	37.6
E21836	+18	5 000	37.6

Notes: Tighter tolerance available on request

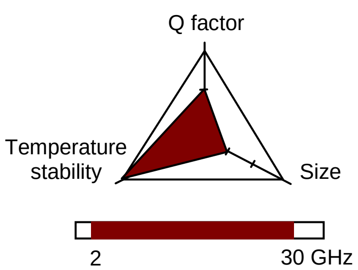
DIELECTRIC RESONATORS

E3000 SERIE



Frequency (MHz)	Diameter range (mm)		
$1980 \le F \le 31230$	$D_{min} = \frac{49500}{F}$	$D_{typ} = \frac{56000}{F}$	$D_{max} = \frac{62500}{F}$
	$2 \le D \le 25$		

Notes: Custom sizes available on request

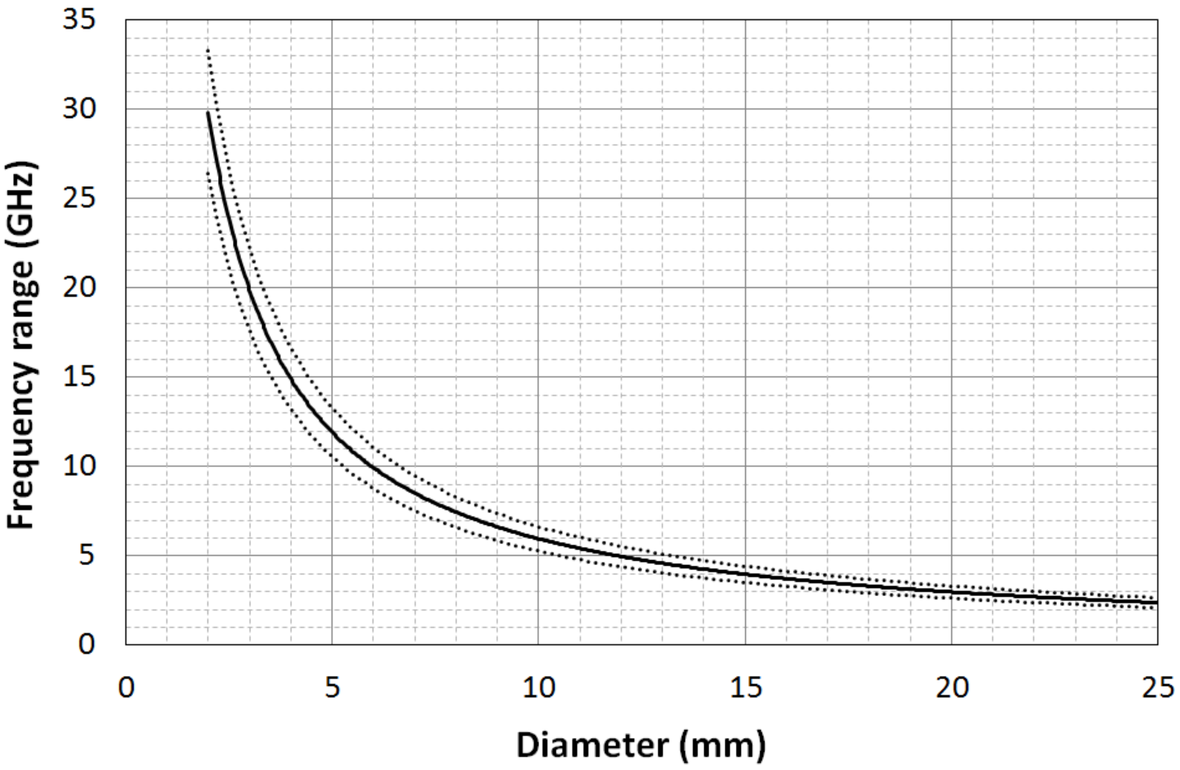


Material	τ_f (ppm/℃) +/-2ppm/℃	Typical Q factor @ 10GHz	Dielectric Constant ε_r +/-1
E3434N	-4	4 000	33.5
E3234N	-2	4 000	33.8
E3034	0	4 000	34.0
E3234	+2	4 000	34.2
E3434	+4	4 000	34.4
E3634	+6	4 000	34.7
E3834	+8	4 000	35.0
E31034	+10	4 000	35.3

Notes: Tighter tolerance available on request

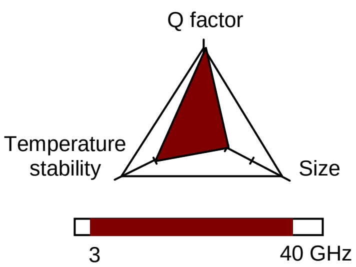
DIELECTRIC RESONATORS

E4000 SERIE



Frequency (MHz)	Diameter range (mm)		
$2110 \leq F \leq 33250$	$D_{min} = \frac{52800}{F}$	$D_{typ} = \frac{59600}{F}$	$D_{max} = \frac{66500}{F}$
	$2 \leq D \leq 25$		

Notes: Custom sizes available on request

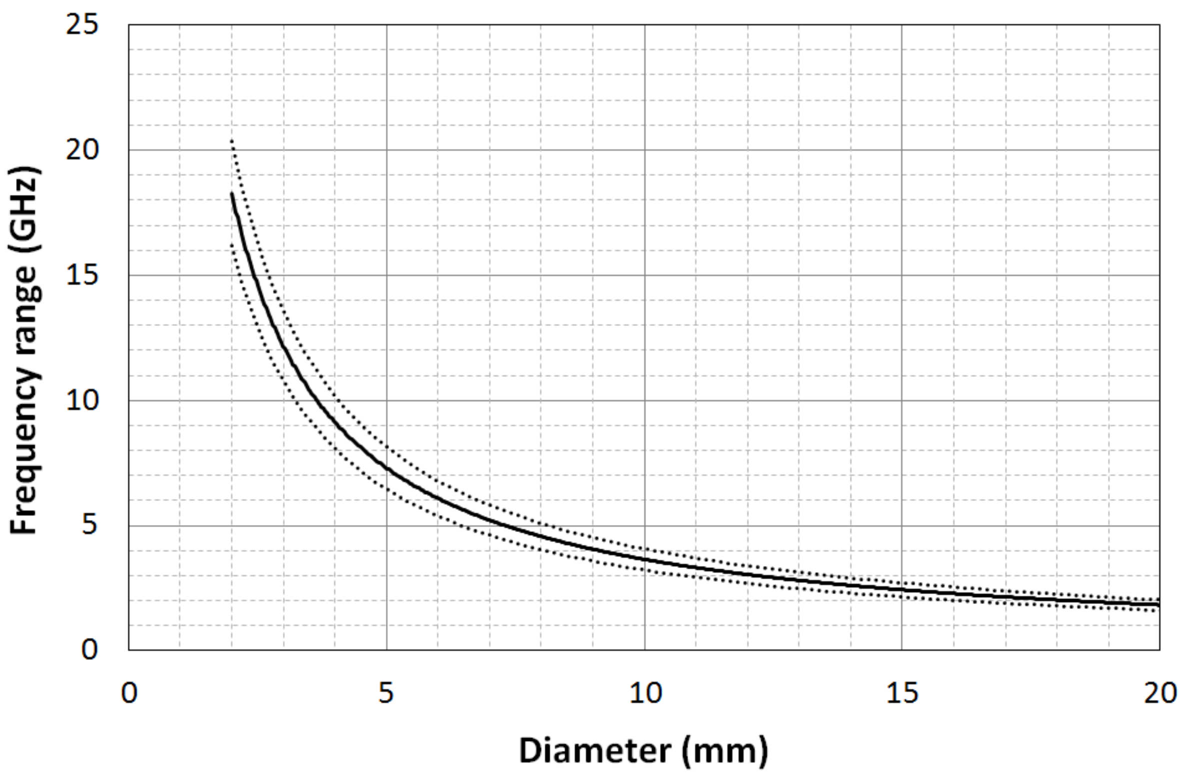


Material	τ_f (ppm/℃) +/-2ppm/℃	Typical Q factor @ 10GHz	Dielectric Constant ε_r +/-1
E4030	0	15 000	29.5
E4230	+2	15 000	30.0
E4330	+3	15 000	30.3
E4430	+4	15 000	30.5
E4630	+6	15 000	31.0
E4830	+8	15 000	31.5
E41030	+10	15 000	32.0

Notes: Tighter tolerance available on request

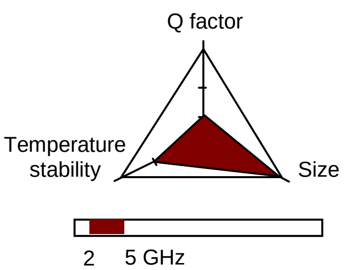
DIELECTRIC RESONATORS

E5000 SERIE



Frequency (MHz)	Diameter range (mm)		
$1620 \leq F \leq 20360$	$D_{min} = \frac{32300}{F}$	$D_{typ} = \frac{36500}{F}$	$D_{max} = \frac{40700}{F}$
	$2 \leq D \leq 20$		

Notes: Custom sizes available on request

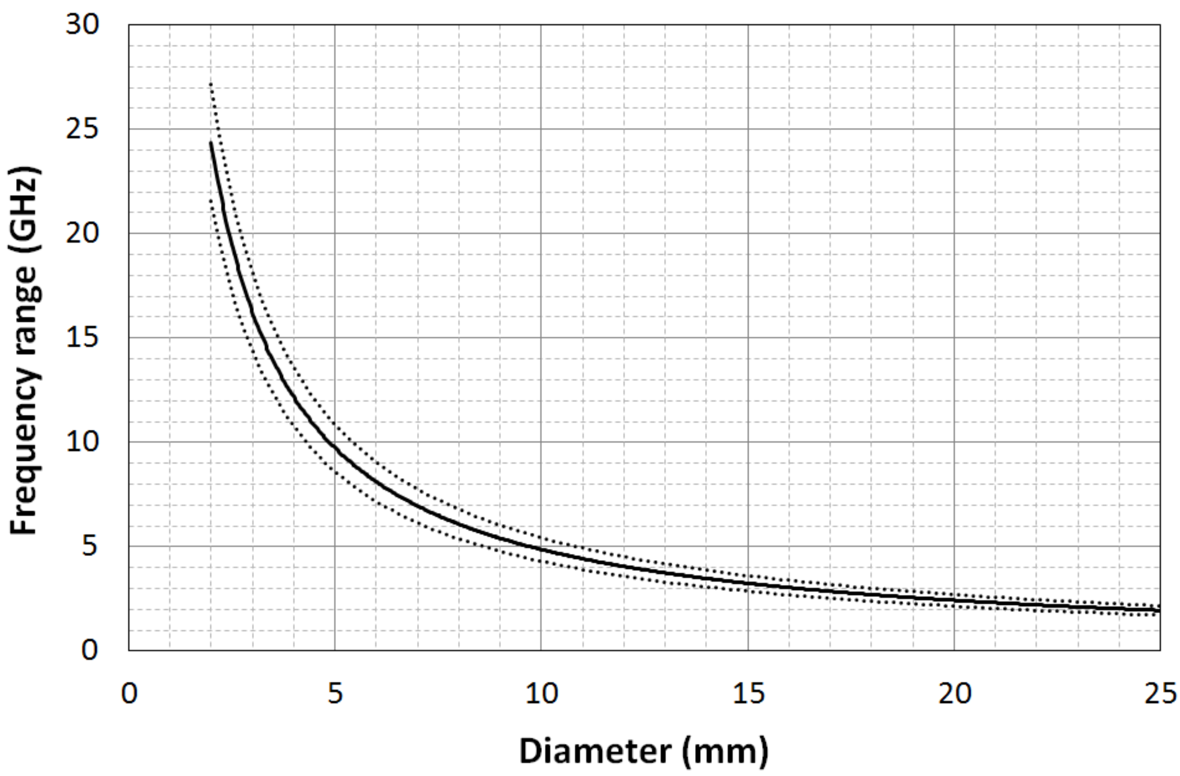


Material	τ_f (ppm/℃) +/-2ppm/℃	Typical Q factor @ 5GHz	Dielectric Constant ε_r +/-2
E5080	0	1 600	78.0
E5380	+3	1 600	78.0
E5680	+6	1 600	78.0
E5980	+9	1 600	78.0

Notes: Tighter tolerance available on request

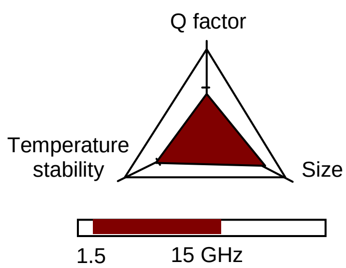
DIELECTRIC RESONATORS

E6000 SERIE



Frequency (MHz)	Diameter range (mm)		
$1720 \le F \le 27150$	$D_{min} = \frac{43100}{F}$	$D_{typ} = \frac{48700}{F}$	$D_{max} = \frac{54300}{F}$
	$2 \le D \le 25$		

Notes: Custom sizes available on request

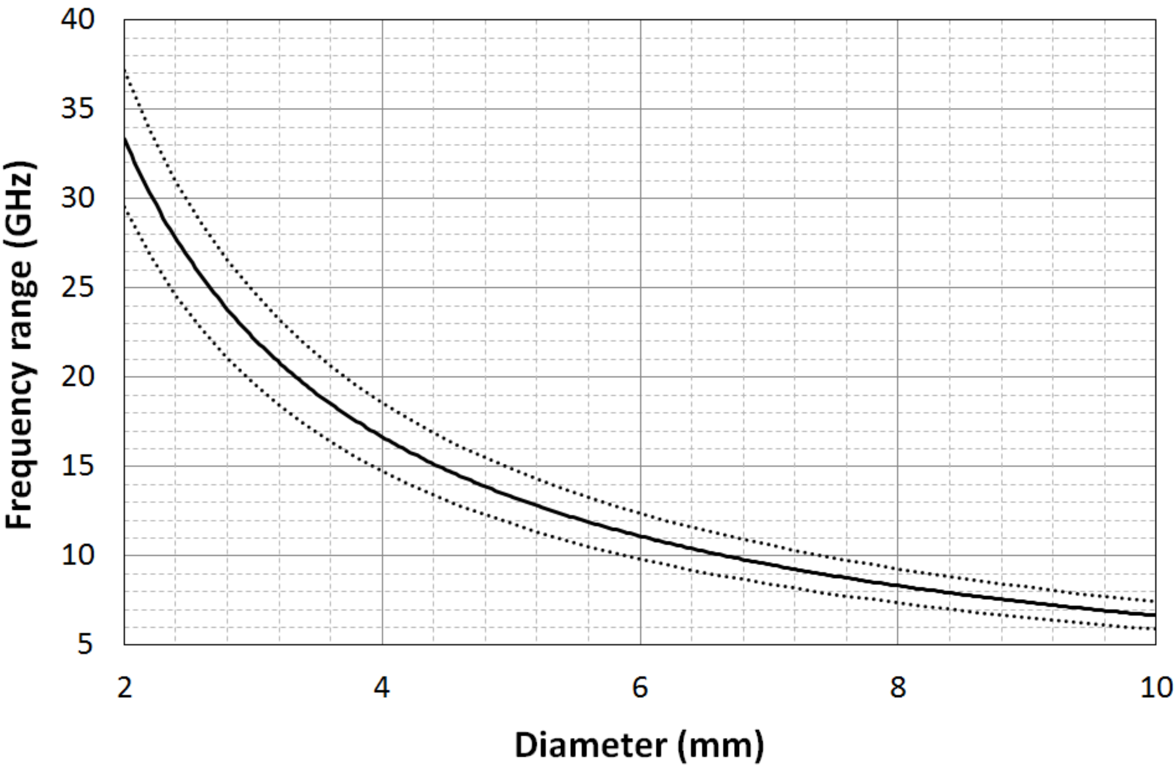


Material	τ_f (ppm/℃) +/-2ppm/℃	Typical Q factor @ 5GHz	Dielectric Constant ε_r +/-1
E6645N	-6	8 000	43.9
E6345N	-3	8 000	44.3
E6045	0	8 000	44.5
E6345	3	8 000	45.0
E6645	6	8 000	45.3
E6945	9	8 000	45.5
E61245	12	8 000	46.0

Notes: Tighter tolerance available on request

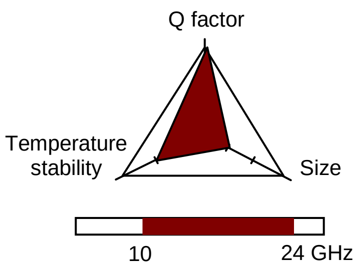
DIELECTRIC RESONATORS

E7000 SERIE



Frequency (MHz)	Diameter range (mm)		
$5900 \leq F \leq 37150$	$D_{min} = \frac{59000}{F}$	$D_{typ} = \frac{66700}{F}$	$D_{max} = \frac{74400}{F}$
	$2 \leq D \leq 10$		

Notes: Custom sizes available on request



Material	τ_f (ppm/℃) +/-2ppm/℃	Typical Q factor @ 10GHz	Dielectric Constant ε_r +/-1
E7024	0	20 000	24.3
E7324	+3	23 000	24.4
E7624	+6	25 000	24.5

Notes: Tighter tolerance available on request

DIELECTRIC RESONATORS

IV. Hi-Rel products

Being involved with all key worldwide space customers, Temex Ceramics has definitely a strong space heritage with its dielectric resonators on this market segments.

Several dielectric materials providing High Q characteristics are available for high-end communication devices (sitcom filters).

E7000 → *Qxf 250 000 @ 10GHz*

E4000 → *Qxf 150 000 @ 10GHz*

LAT tests available for Hi-rel models

Withstand strong environmental conditions

Thermal cycling: 50 cycles -55℃/+125℃

Life test: 1000 hours at 125℃