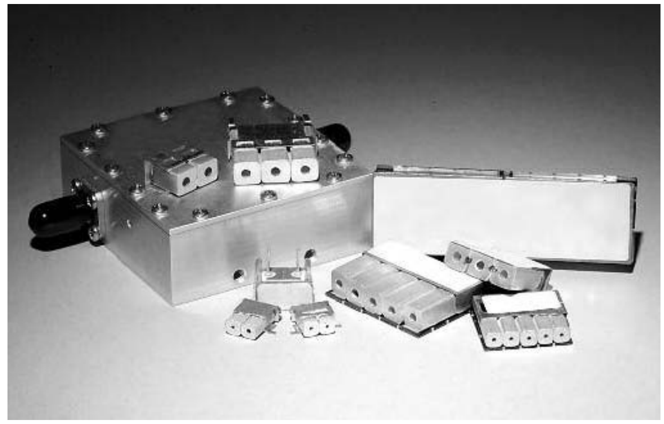
APPLICATION NOTE

Introduction and Applications for Temperature-Stable Dielectric Resonators

Applications

- Filters and combiners:
  - Cellular base station
  - PCS/PCN
- Direct broadcast satellite receivers
- Police radar detectors
- LMDS/MMDS wireless cable TV
- Automobile collision avoidance sensors
- DR antennas
- Motion detectors



Introduction

Trans-Tech Inc. (TTI) manufactures millions of Dielectric Resonators (DRs) each year for commercial and military markets, at frequencies from below 850 MHz to above 32 GHz.

The DRs satisfy the need for compact, temperature-stable, high Qu-factor microwave resonating elements. The DRs are well understood and documented in engineering literature, and are commonly used in DR Oscillators (DROs) and low-loss filters. In this document, TTI refers to unmetallized ceramic cylinders with or without an inner diameter that are intended to operate in the TE_{01} mode, which is the most commonly used DR mode for filters and oscillators.

The ceramic resonator is usually supported between a metal floor and a metal roof, sometimes (as in oscillators) with an intervening substrate attached to the metal floor. When used, the support is a low-loss, low dielectric constant material that provides space between the DR and the metal floor. That space differs for filters and oscillators.

There are usually metal sidewalls to complete a conducting boundary enclosing the DR. TTI refers to this enclosure as a "cavity." The cavity itself is not intended to be resonant without the ceramic DR. The resonant frequency of the TE_{01} mode DR is dependent upon not just the ceramic, but also the cavity size and the mounting of the DR within the cavity.

The same ceramic DR gives a different resonant frequency in a different cavity because nearby conducting surfaces perturb the RF magnetic field of the TE_{01} mode, and the closer the metal is to the DR, the higher the frequency. This principle of operation is totally different than Transverse Electro-Magnetic (TEM) (coaxial) resonators, where the RF fields are contained primarily within the metallized ceramic.

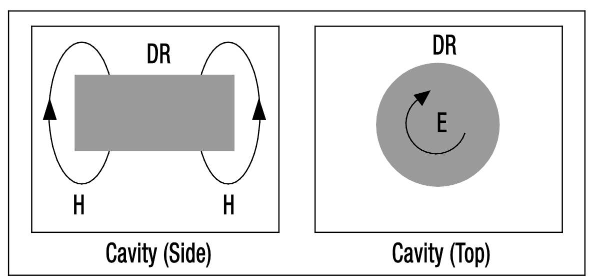


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Figure 1. TE_{01} Mode DRs

Material Types

Table 1. Overview by Material Type

Type	E'	Q x F	Relative Cost/ Volume	Linearity
8300	36	41,000	Lowest	Excellent
4300	43	43,000	Low	Good
4500	45	41,000	Low	OK for small temperature range(s)
3500	35	70,000	Moderate	Excellent
8700	30	100,000	High	Good
2900	30	110,000	High	Good

Note: The Q x F product applies when the cavity size is large enough that metal wall losses can be neglected (cavity size is approximately three times the DR size), and somewhat below 2 GHz.

8300

Available in a wide range of temperature coefficients, the 8300 is a heavy-duty composition that combines good Qu with low cost. Wideband filter applications benefit from the E'36 for coupling that is easier to achieve than with the 4300 or 4500 series. Millions of Ku-band Low-Noise Block (LNB) assemblies of 8300 material with alumina supports have been delivered in tape-and-reel format.

4300

Popular for narrow-band Universal Mobile Telephone System (UMTS) filter applications, the 4300 series is the correct choice for size reduction, where good linearity is required for temperature compensation.

3500

Introduced in June 2000, the 3500 series provides a Qu boost from generic E'36 ceramics, but without the costly high tantalum content. The 3500 material is popular in narrow-band 2 GHz filter applications and X/Ku-band satellite LNBs where better phase noise performance is required.

4500

Originally developed with Advanced Mobile Phone System (AMPS) and Global System for Mobile Communications (GSM) auto-tuned cellular combiners in mind, the 4500 series offers the best size reduction vs Qu trade-off where some non-linearity of Fo versus temperature can be tolerated (e.g., moderate-bandwidth filters).

2900

Originally developed for narrow-band Personal Communications System (PCS) and Digital Cellular System (DCS) auto-tuned combiners, where the highest Qu was paramount. The 2900 material is occasionally used in multiple filters where the highest Qu is needed for the lowest losses. Sizes have been produced for applications as low as 1800 MHz, but the tantalum additives increase the cost.

8700

A predecessor of the 2900 series, the 8700 is still popular at high frequencies, generally above 4 GHz. TTI produced the 8700 material for automotive collision avoidance and motion-detection DROs near 24 GHz, and fiber-optic clock-recovery applications near 38 GHz. The low E'30 facilitates manufacturing tolerances for the highest frequency small part sizes.

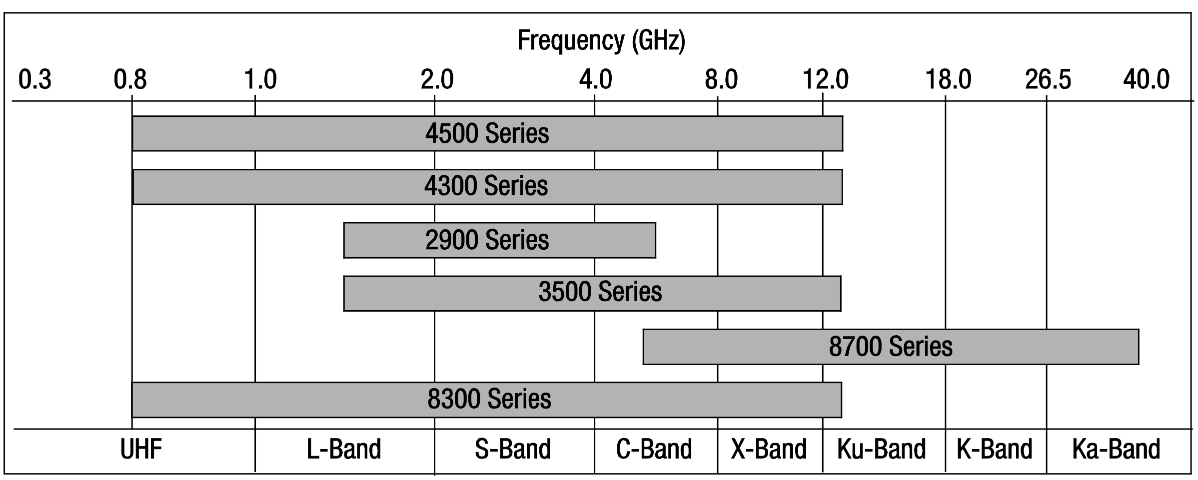

Figure 2. Suggested Frequency Range for DR Materials

Note: The Figure presents a summary overview of the temperature-compensated DR materials available from TTI.

Table 2. Summary of Product Characteristics of DR Materials

Product Characteristics	4500	4300	2900	3500	8700	8300
Dielectric constant	44.7 to 46.2	800 to 13,800	29.0 to 30.7	34.5 to 36.5	29.5 to 31.0	35.0 to 36.5
Q (1/tanδ)	>9,500 at 4.3 GHz	>9,500 at 4.3 GHz	>50,000 at 2.0 GHz	>35,000 at 2 GHz	10,000 at 10.0 GHz	>9,500 at 4.3 GHz
Available frequency (MHz):						
Disc type	800 to 13,800	800 to 13,800	1500 to 5550	1500 to 13,800	5550 to 32,150	800 to 13,800
Cylinder type	800 to 9010	800 to 9010	1500 to 5550	1500 to 9010	5550 to 9870	800 to 9010
Available τf (ppm/°C)	6/3/0/3/6	6/3/0/3/6	4/2/0/2	6/3/0/3	4/2/0	9/6/3/0/3
Available τf tolerance (ppm/°C)	± 2 or ± 1	± 2 or ± 1	± 2 or ± 1	± 2 or ± 1	± 2 or ± 1	± 2 or ± 1
Composition	Zr Titanium-based	Zr Titanium-based	BaZnTa oxide	BaZnCoNb	BaZnTa oxide	Titanate-based

Note: All components manufactured based on capability and customer design.

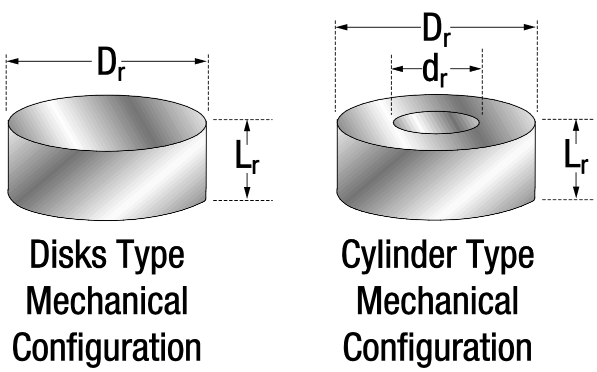

Figure 3. Standard DR Diameters and Sizes

Disk Cylinder Assemblies

Table 3. Standard Outside Diameter (D_r)

0.975 ± 0.002	0.470 ± 0.001	0.200 ± 0.001
0.905 ± 0.001	0.435 ± 0.001	0.190 ± 0.001
0.840 ± 0.001	0.405 ± 0.001	0.180 ± 0.001
0.785 ± 0.001	0.375 ± 0.001	0.170 ± 0.001
0.730 ± 0.001	0.350 ± 0.001	0.160 ± 0.001
0.675 ± 0.001	0.325 ± 0.001	0.150 ± 0.001
0.630 ± 0.001	0.305 ± 0.001	0.140 ± 0.001
0.585 ± 0.001	0.285 ± 0.001	0.130 ± 0.001
0.545 ± 0.001	0.265 ± 0.001	0.120 ± 0.001
0.505 ± 0.001	0.245 ± 0.001	0.112 ± 0.001
	0.230 ± 0.001	0.104 ± 0.001
	0.215 ± 0.001	0.096 ± 0.001
		0.089 ± 0.001
		0.082 ± 0.001
		0.076 ± 0.001

Table 4. Standard Inside Diameter (d_r)

0.162 ± 0.004
0.122 ± 0.004
0.083 ± 0.004

For cellular and PCS applications, TTI offers customized products in 4500, 2900, and 8300 series materials. For high frequency applications, TTI offers 4500, 8700, and 8300 series materials. Table 2 provides the suggested dimensions for each series.

TTI offers a broad range of standard catalog sizes that are approximately tailored for frequency. All sizes are custom, and are not to be interpreted as limitations in dimensions. The optimum DR is uniquely sized for each application. For each diameter, TTI suggests a height range (L_r) that is 35% to 45% of the resonator's diameter. This ratio is optimum for spurious mode-free operation in the case of an isolated resonator [reference 1], but does not guarantee mode separation where the DR enclosure influences performance.

TTI also offers DRs with center holes (cylinders), generally in specified Inner Diameters (IDs). The ID raises the frequency above that of a solid DR by 1% to 2% if the inner hole is less than one-fourth the resonator's diameter [reference 2]. The inner hole tends to increase separation of the TE_{01d} mode frequency from that of higher-order modes.

The more practical reason for choosing a cylindrical resonator is the ease of mounting with a low dielectric constant non-conducting screw, such as nylon. Supports are available with companion IDs for screw clearance. To reduce costs, the IDs of the cylindrical resonators are less critically toleranced than the outer diameters. This is no disadvantage when the DRs are properly sized for frequency, as previously described.

Dielectric Resonator (DR) Part Numbering

DRs can be ordered by dimensions only (rather than frequency-tuned) with the following part numbering system.

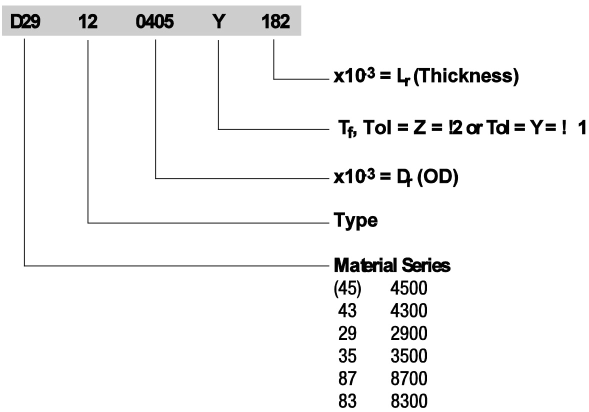

Figure 4. Disk Type Example—D2912-0405-Y-182

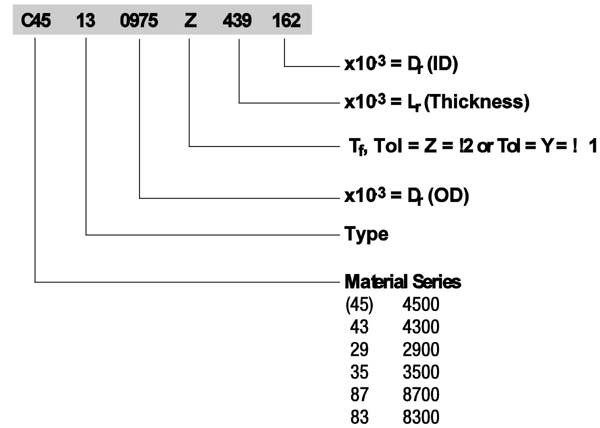

Figure 4. Cylinder Type Example—C4512-0975-Z-439-162

References

[1] S. Cohn: *Microwave Bandpass Filters Containing High-Q Dielectric Resonators*, IEEE Transactions on Microwave Theory and Techniques, Volume MTT-16, No. 4, April 1968.

[2] Mongia: *Easy Resonant Frequency Computations for Ring Resonators*, Microwave Journal, November 1992