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Basic Data on High-Q Ceramic Coaxial Resonators

Ceramic coaxial resonators have become an everyday sight in engineering development laboratories and manufacturing production lines. These components use the size-reducing effects of high diectric constant ceramic materials to make the smallest possible resonators for VCOs and filters operating from VHF to microwave frequencies.

Figure 1 shows the typical construction of a commercially available ceramic resonator. The configuration is coaxial, with an approximately square cross-section outer conductor and a round (cylindrical) center conductor. Physical dimensions for a particular coaxial element are *W*, *d* and *l*. Together with the dielectric constant of the ceramic material, ε_r, the approximate coaxial line characteristic impedance can be calculated by:

$$Z_0 = \frac{60}{\sqrt{\varepsilon_r}} \ln\left(1.08 \frac{W}{d}\right)$$

Commonly-used products typically have Z_0 in the range of 5 to 15 ohms.

The electrical length of a coaxial line is affected by ε_r as follows:

$$\lambda_{\text{effective}} = \frac{\lambda_{\text{free space}}}{\sqrt{\varepsilon_r}}$$

Since the ceramics used in these coaxial elements have ε_r from 10 to more than 100, so we can see from the above equation that the electrical length can be reduced by a factor of ten or more from the free space length. For example, a 300 MHz 1/4-wavelength line section with ε_r of 90 has a length of 1.037 in. (26.3 mm), compared to a free space length of 9.84 in. (250 mm).

The typical resonator consists of a shorted $\lambda/4$ line section, although an open-circuit $\lambda/2$ line may be used for some applications. Typically, a ceramic coaxial element can be obtained in a specified length, with one end plated to "short-circuit" the center conductor to the outer conductor.

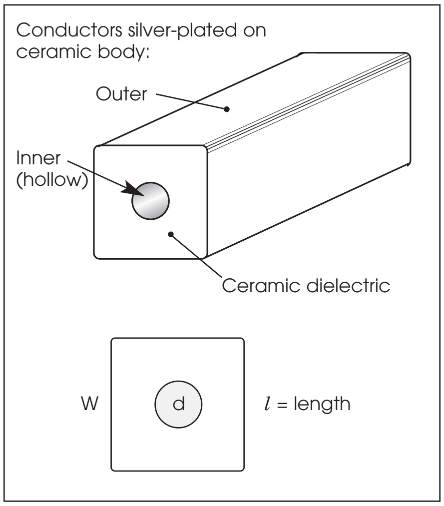

Figure 1 · Construction of a ceramic coaxial resonator and its physical dimensions.

Resonator Q can vary significantly with different materials, frequencies and size, but will have a value in the hundreds (~150 to 500).

Tuning the Resonator

For VCO applications the resonator must be tuned over a significant frequency range. The simplest method for doing this is to select a coaxial element with a self-resonant frequency (SRF) that is 20 to 30 percent higher than the operating frequency, where it will present an inductive reactance. Parallel capacitance (e.g. a varactor tuning diode) can then be added to obtain resonance at the desired frequency.

The inductive reactance of a coaxial line can be approximated using:

$$X_L = Z_0 \tan(\Theta)$$

where Z_0 is the characteristic impedance of the line, and Θ is its electrical length in radians. ($\Theta = 2\pi l/\lambda_{\text{eff}}$, where λ_{eff} is the wavelength in the dielectric at the operating frequency.)

This value of inductance (actually, a range of values, since it varies with frequency), can be used to design the desired VCO circuit.

Tuning of resonators for filters does not necessarily mean production line tweaking. Often, resonators are tuned with fixed capacitors to compensate for the shift in resonance due to different coupling coefficients between filter sections. This enables a single resonator type to be used in a typical "stagger-tuned" filter.

Cautions and Caveats

There are physical limitations in the ceramic resonator manufacturing processes. Each manufacturer will have a recommended range of SRF for each product, which is governed by practical lengths for each cross-section profile. Consult with the supplier if you want a resonator at the limits of the recommended sizes.

High reactance values can be obtained close to resonance. If such use is considered, examine such factors as temperature stability (of the resonator *and* the surrounding circuitry) and manufacturing tolerances from piece-to-piece and lot-to-lot.

Finally, remember all the stray and parasitic reactances and resistances: the effect of plating on the shorted end, the inductance of the inner conductor connecting tab, and the effects due to the PC board mounting method and proximity to adjacent components.