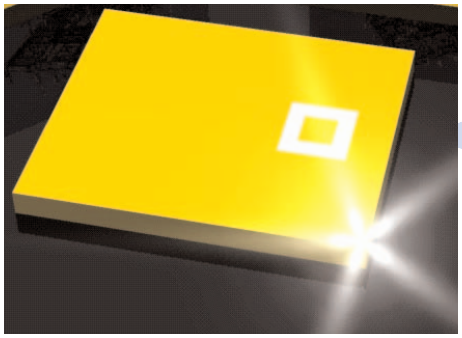
Single Frequency Cavity Resonator™

Patent Pending

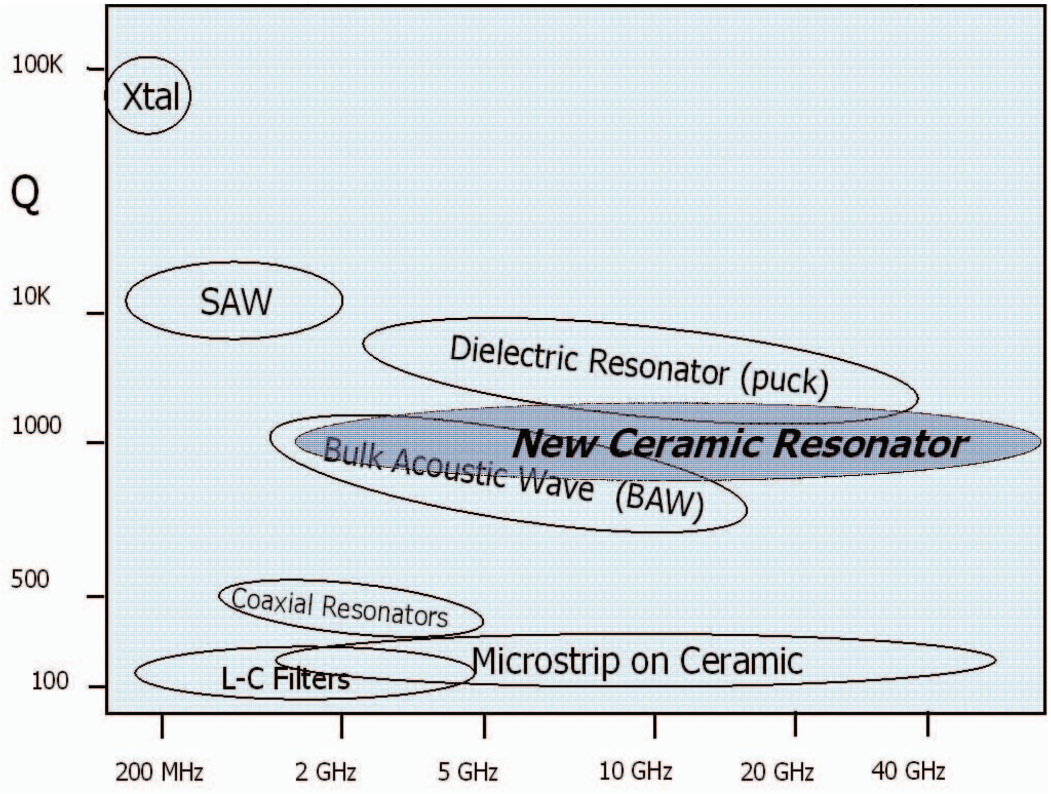
DLI's Cavity Resonators set a new standard for high Q resonator performance across a broad spectrum of frequencies. High Q resonators play a critical role in system noise performance, and employing this advantage is dramatically easier and less expensive than ever before. These products include extremely stable Single Frequency Cavity Resonators (SFCR), Wide-Band Tunable Ceramic Resonators, and Two-Port Resonators described in more detail on the following pages.

DLI has introduced a family of patent pending high-Q temperature stable cavity resonators. They provide an ideal solution for high performance, low-cost microwave or millimeter-wave oscillators and filters. This component has integral shielding, controlled coupling and tight frequency tolerances. Devices are available in both surface mount technology (SMT) and wire-bond forms, enabling automated assembly. The unique features of this patent pending device reduce circuit size and weight and eliminate the expense of fully shielded housings, manual assembly and manual frequency tuning.



- *Fully shielded*
- *Surface mountable or wire-bondable*
- *Q's up to 2000+*
- *Frequency ranges from 1 to > 67 GHz*
- *Excellent frequency stability vs. temperature*
- *High reliability thin film gold metallization*
- *Frequency tolerances as low as 0.1%*

Q Comparison of Various Resonator Technologies



Dielectric Laboratories Inc.
2777 Route 20 East
Cazenovia, New York, USA
13035-9433

phone 315.655.8710
fax 315.655.0445
www.dilabs.com

email sales@dilabs.com
or europesales@dilabs.com
or asiasales@dilabs.com

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A Sample of Applications:

Systems

Automotive

RADAR
- Ground-based
- Avionics/Missile
- Shipboard

Communications
- Base Stations
- WLAN, WLL
- SONET/SDH

Military
- RFID
- ECM/ECCM/EW
- Tx/Rx
- Man Pack Radio
- Aerospace
- Intelligent Munitions

Instrumentation

Circuits

Microwave & Millimeter-Wave Oscillators

Fundamental Fixed Frequency Oscillators - Ultra-low Phase Noise
(*former solution*: expensive DRO's and multiplied-up crystal or SAW based device with decreased performance)

Narrow-Band Tunable VCO or Phase Locked Oscillators
(typically ± 0.3% tuning)
(*former solution*: varactor tuned expensive DRO)

Integration of high performance Oscillators directly on the system motherboard *without the expense and complexity of subassemblies, housing and labor intensive operations typical of former solutions.*

Narrow bandwidth low loss filters
(*former solution*: low loss SAW devices with frequency limitation and poor performance)

Comparison of a DLI 10 GHz Single Frequency Cavity Resonator (SFCR) With Competing Technologies

	DLI SFCR	DRO "Puck"	Ceramic Coaxial	L-C	SAW	BAW	Microstrip
Frequency Range (GHz)	**1 – 67+**	1 ~ 40	0.5 ~ 5	~0 - 3	0.1 ~ 3	1 ~ 10	0.5 ~ 100
Self Shielding	**Yes**	No	Yes	No	Yes	Yes	No
SMT Capable	**Yes**	No	Yes	Difficult	Yes	Yes	Yes
Chip & Wire Compatible	**Yes**	No	No	Difficult	Contamination Sensitive	Contamination Sensitive	Yes
Q @ 2 GHz	**→ 1500**	→ 15000	~ 500	50~150	5~10000	1000~2000	100~200
All data below is for a 10 GHz resonator							
Q	**→ 2000**	→10000	N/A	N/A	N/A	500 ~ 1000	100 ~ 300
Size (inches) X	**0.17**	1 (housing)	N/A	0.15	N/A	0.1	0.2
Y	**0.2**	1 (housing)	N/A	0.15	N/A	0.2	0.1
Z	**0.06**	0.5 (housing)	N/A	0.1	N/A	0.05	0.1
Volume (in^3)	**$2x10^{-3}$**	0.5	N/A	$\sim 2x10^{-3}$	N/A	N/A	$\sim 2x10^{-3}$

XTREME-Q™

Single Frequency Cavity Resonator

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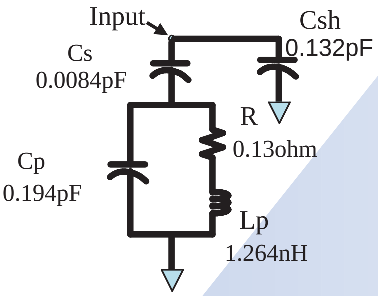
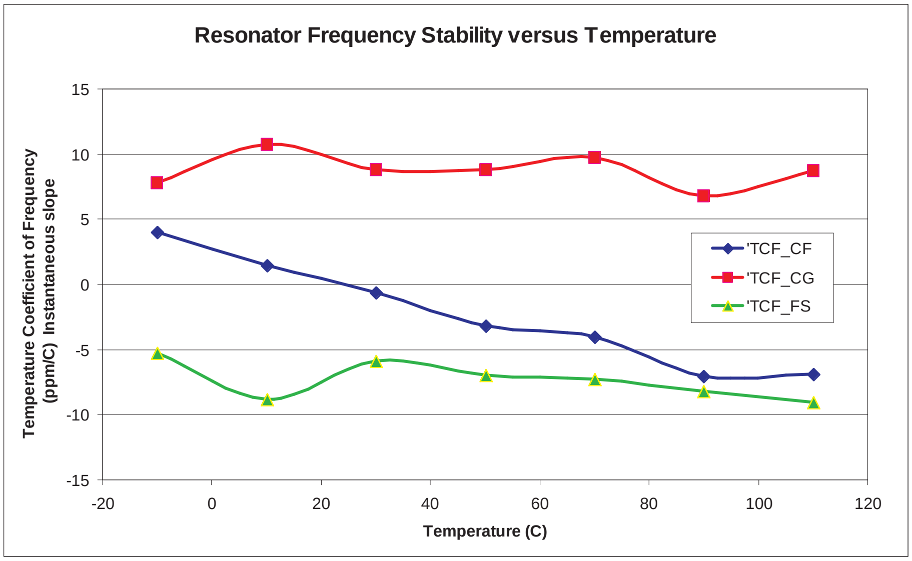
Part Identification Number					
ACR	**08250**	**CF**	**1**	**S**	**T**
Product Family	Resonant Frequency	Material Code	Frequency Tolerance	Mounting Code	Package
	GGmmm Example: 08250=8.25 GHz	CF, CG, FS	1= ± 0.1% 2= ± 0.2% 3= ±0.5% 4= ±1.0% 9= special	S=Surface Mount (SMT) W=Microstrip Mount (see page 9)	T=Tape/Reel P= Waffle Pack



Equivalent Circuit of a 9.95 GHz SFCR

The equivalent circuit of the Single Frequency Cavity Resonator (SFCR) near its lowest resonant frequency is shown at left. The lowest resonant mode is typically employed in oscillator and filter designs. The element values are shown for a 9.95 GHz SFCR. The resonant frequency is set by the parallel combination of Cp and Lp, and the finite unloaded Q by R. The series capacitance Cs connects the resonator L-C to the input pad, thus setting the coupling between the external circuit and the frequency controlling L-C resonator. The capacitance Csh is a stray capacitance between the input pad and ground. All of these network elements have excellent repeatability providing tight control over resonant frequency, coupling and input impedance. The structure also provides an integrated DC blocking function, thus eliminating a tolerance sensitive element from the bill of materials. For wide bandwidth circuit modeling, S-Parameters are recommended. S-Parameters are available for downloading from our website (www.dilabs.com). The resonators are readily customized for frequency, coupling, Q, tunability and assembly requirements. For additional information on custom solutions see pages 14-16.

The Graph below depicts typical Single Frequency Cavity Resonator frequency stability versus temperature for DLI standard dielectric materials.



Dielectric Laboratories Inc.
2777 Route 20 East
Cazenovia, New York, USA
13035-9433

phone 315.655.8710
fax 315.655.0445
www.dilabs.com

email sales@dilabs.com
or europesales@dilabs.com
or asiasales@dilabs.com

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Measured Data from Selected Standard Resonators

Resonant Frequency (GHz)	*Temperature Coefficient of Frequency* Typical (ppm/°C)*	*Return Loss @ Resonance Typical (dB)*	*Loaded Q Typical (50 Ohms)*	*Dimensions L x W x T*	
				mm	*inches*
8.20	CF Material: - 2.3	-25	250	5.3 x 5.3 x 0.8	0.21 x 0.21 x 0.03
9.95	CF Material: - 2.3	-11	300	5.6 x 4.3 x 0.8	0.22 x 0.17 x 0.03
12.80	CF Material: - 2.3	-7	350	3.8 x 3.6 x 0.8	0.15 x 0.14 x 0.03
18.65	FS Material: - 7.3	< -25	400	6.1 x 5.6 x 1	0.24 x 0.22 x 0.04

* over the range -20°C to +120°C

The table above summarizes the characteristics of selected standard resonators, and below some selected simulations to illustrate the primary resonator design variables. The primary variables are frequency of resonance, cavity material dielectric constant, and length and width dimensions. The interaction of these variables is illustrated in the resonator size charts on the page 8. The loaded Q of the resonators is effected by the coupling coefficient (denoted in the tables in terms of return loss) and by material choice (dielectric constant), and by material thickness. Generally, resonators made from thick, low dielectric constant materials are capable of the highest loaded Q's. For reference, when a resonator has a coupling coefficient of 1.0 it will exhibit an excellent return loss at the resonance frequency and the unloaded Q of the resonator will be 2 times the loaded Q value. The desired level of resonator coupling varies with individual circuit requirements such as varactor frequency trimming, or transistor negative resistance value. Resonator input impedance versus frequency and coupling level are illustrated in the Smith Chart on page 16. The unloaded Q's of the cases shown range up to nearly 2000, clearly a new performance standard for a component compatible with automated assembly. In contrast to other "high Q" microwave resonators, DLI's cavity resonator is completely self contained, that is its loaded Q and resonant frequency can be directly measured using RF coplanar probe technology. Thus, ambiguities of special test fixtures and components which are not appropriate to the product realization are eliminated from part evaluation.

Simulated Data for Selected Resonators

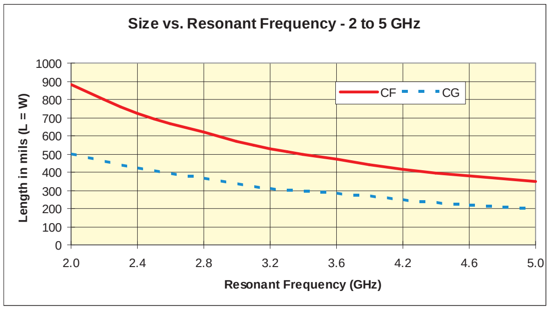
Resonant Frequency (GHz)	*Temperature Coefficient of Frequency* Typical (ppm/°C)*	*Return Loss @ Resonance Modeled (dB)*	*Loaded Q Modeled (50 Ohms)*	*Dimensions L x W x T*	
				mm	*inches*
3.2	CG Material: 8.8	-22	290	8.1 x 8.1 x 3	0.32 x 0.32 x 0.12
5.0	CF Material: - 2.3	-12	550	8.1 x 8.1 x 3	0.36 x 0.36 x 0.12
	CG Material: 8.8	-12	360	5.1 x 5.1 x 3	0.20 x 0.20 x 0.12
	FS Material: - 7.3	-12	1000	21.8 x 21.8 x 3.8	0.86 x 0.86 x 0.15
24.0	CF Material: - 2.3	-12	480	2.0 x 2.0 x 1.3	0.08 x 0.08 x 0.05
	FS Material: - 7.3	-12	1000	4.6 x 4.6 x 3	0.18 x 0.18 x 0.12
26.5	FS Material: - 7.3	-20	325	4.2 x 4.2 x 0.5	0.16 x 0.16 x 0.02
40.0	FS Material: - 7.3	-18	445	2.7 x 2.7 x 0.5	0.10 x 0.10 x 0.02
50.0	FS Material: - 7.3	-17	400	2.2 x 2.2 x 0.5	0.08 x 0.08 x 0.02
67.0	FS Material: - 7.3	-12	600	1.6 x 1.6 x 1	0.06 x 0.06 x 0.04

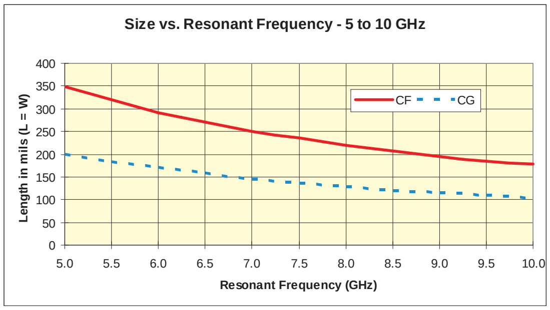
* over the range -20°C to +120°C

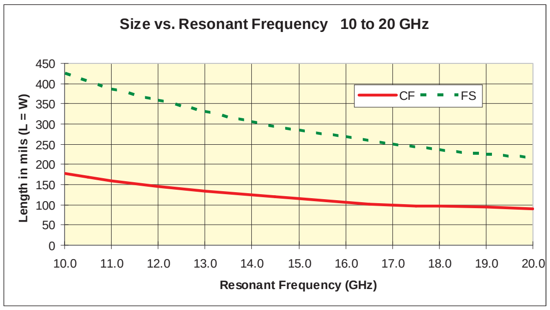
Estimating Resonator Size

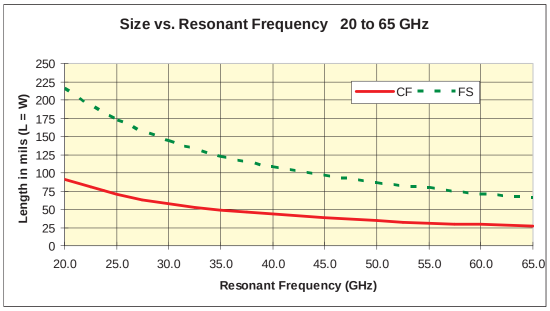
The size of the Cavity Resonator is determined by the desired resonant frequency and the ceramic material selected. Generally, for a given frequency resonator, selecting material types which result in larger part size also result in higher Q resonators. Increased resonator height also enhances Q. For additional information consult the factory.

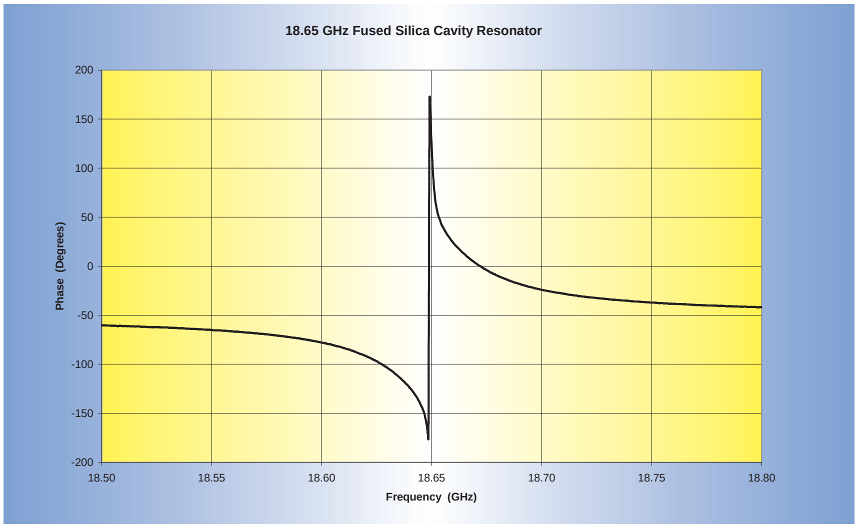
The charts on this page should be used as a guide for selecting the ceramic materials to be used and to closely estimate the resonator length dimension for a square device. Typical designs are nominally rectangular, with length to width aspect ratios of less than 1.2:1.





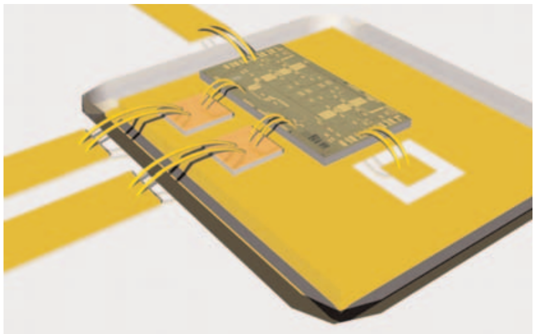






In Oscillators, the most important factor effecting phase noise performance is high resonator loaded Q. High Q is evidenced in the following graph by rapid phase slope (versus frequency) and in the narrow bandwidth of the input reflection coefficient data on pages 10-13.

Mounting Alternatives



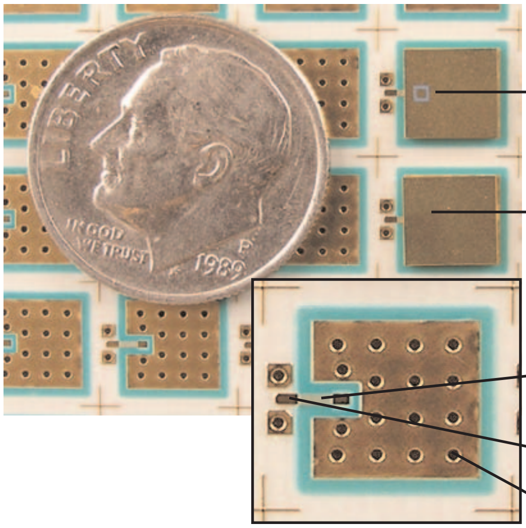
Microstrip Mount

The metallized Cavity Resonator offers unique miniaturization opportunities. Shown is an implementation where the active device and power supply bypass capacitors are assembled onto the resonator. The wirebond signal leads are kept short.

Resonator Mounting, Interconnection and Metallization Schemes

Mounting Code			Backside Metallization	Topside Metallization
Surface Mount S	Component to Circuit Interface	Solder - Sn/Pb or Sn [Lead free] Or Conductive Epoxy	Nickel/Gold	Nickel/Gold
Microstrip Mount W	Component to Substrate Interface	Conductive Epoxy	Gold	-
	Input/Output Interconnect	Thermocompression - Wirebond	-	Gold

For more information on metallization codes, see page 19



Resonator mounting surface shown facing up (contact pad is visable)

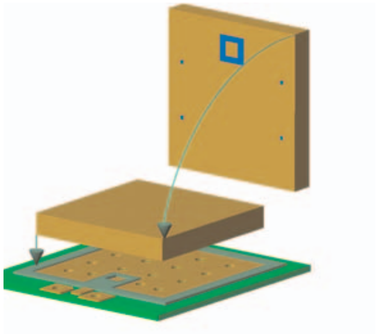
SMT resonator shown in normal mounted orientation

Typical circuit board layout for SMT resonator mounting:

a) Solder mask, insulates input line from shorting to ground

b) Input line

c) Ground Vias in board



This illustration demonstrates a surface mounting technique. The first resonator is positioned with the I/O pad in view to demonstrate the alignment with the printed wire board geometry. The second illustration shows the resonator mounted in position. The third illustration shows the printed wire board geometry. A solder mask is used to control the flow of solder during assembly and insulate the input-line from shorting to the resonator ground metallization.

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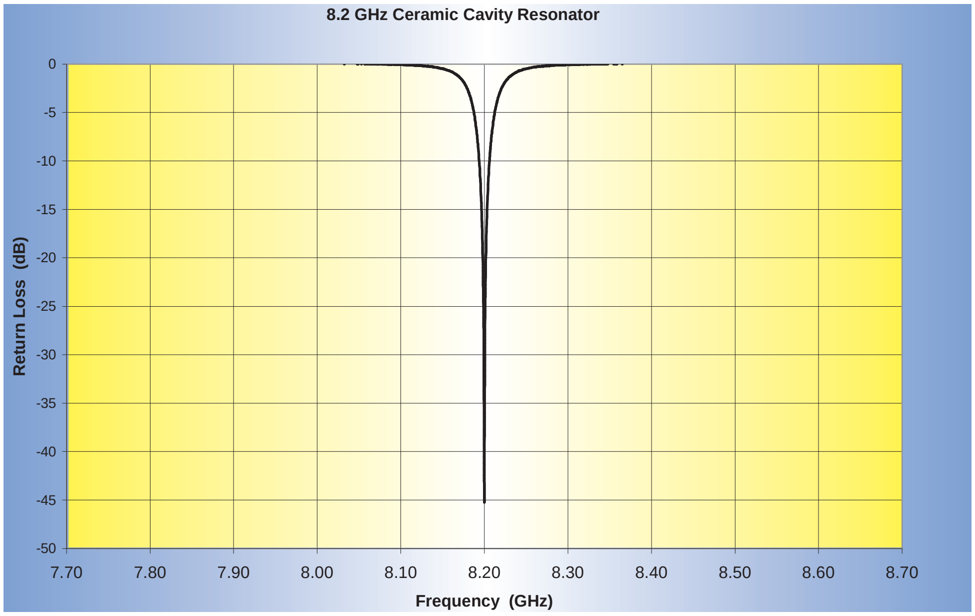
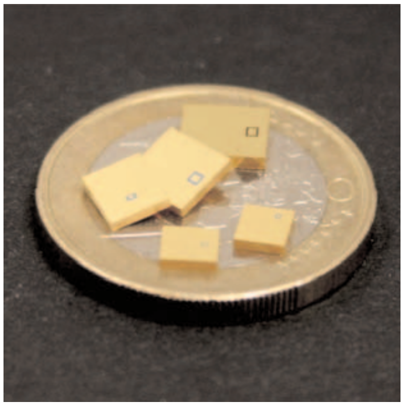
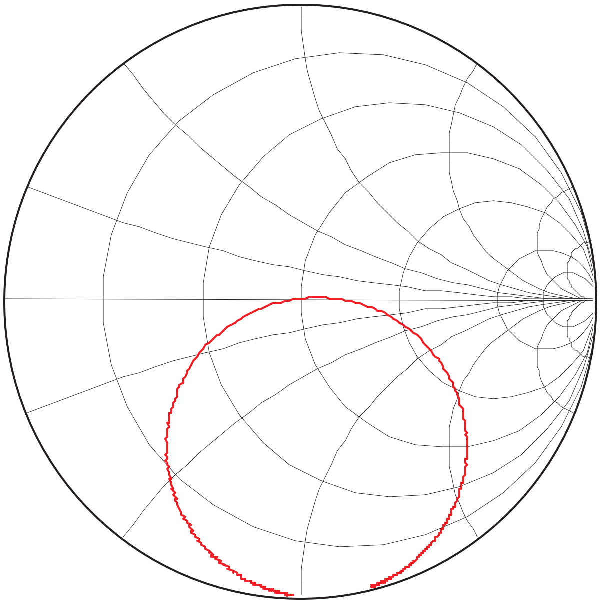
8.2 GHz Cavity Resonator



Resonant Frequency (GHz)	*Temperature Coefficient of Frequency* Typical (ppm/°C)*	*Return Loss @ Resonance Typical (dB)*	*Loaded Q Typical (50 Ohms)*	*Dimensions*	
				mm	*inches*
8.20	CF Material: - 2.3	-25	250	5.3 x 5.3 x 0.8	0.21 x 0.21 x 0.03

* over the range -20°C to +120°C



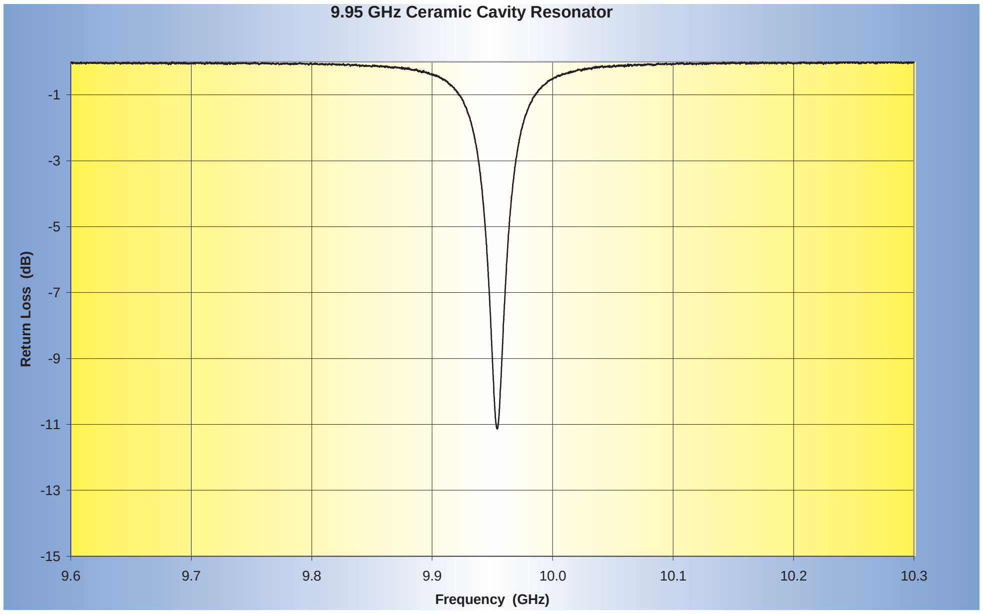


Dielectric Laboratories Inc.
2777 Route 20 East
Cazenovia, New York, USA
13035-9433

phone 315.655.8710
fax 315.655.0445
www.dilabs.com

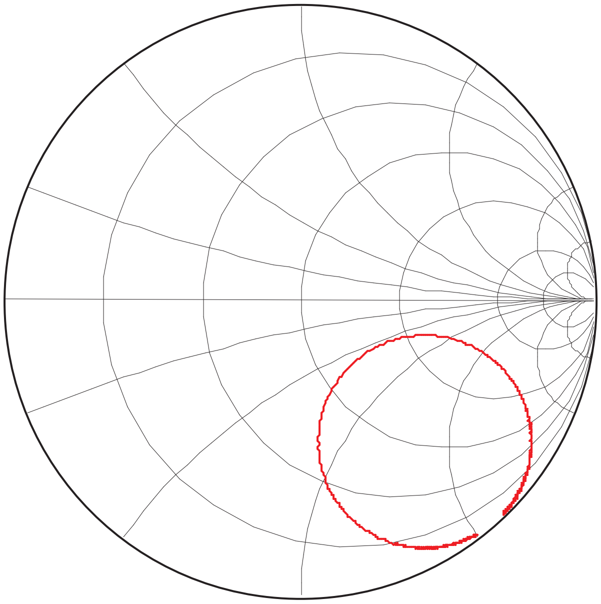
email sales@dilabs.com
or europesales@dilabs.com
or asiasales@dilabs.com

9.95 GHz Cavity Resonator



Resonant Frequency (GHz)	***Temperature Coefficient of Frequency* Typical (ppm/°C)***	***Return Loss @ Resonance Typical (dB)***	***Loaded Q Typical (50 Ohms)***	***Dimensions***	
				mm	***inches***
9.95	CF Material: - 2.3	-11	300	5.6 x 4.3 x 0.8	0.22 x 0.17 x 0.03

* over the range -20°C to +120°C



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Single Frequency Cavity Resonator

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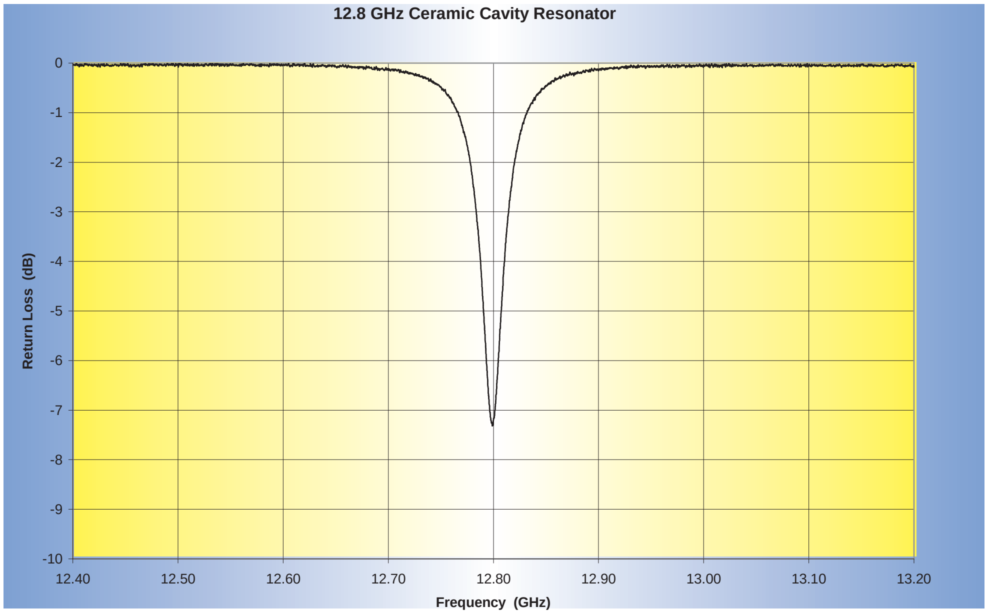
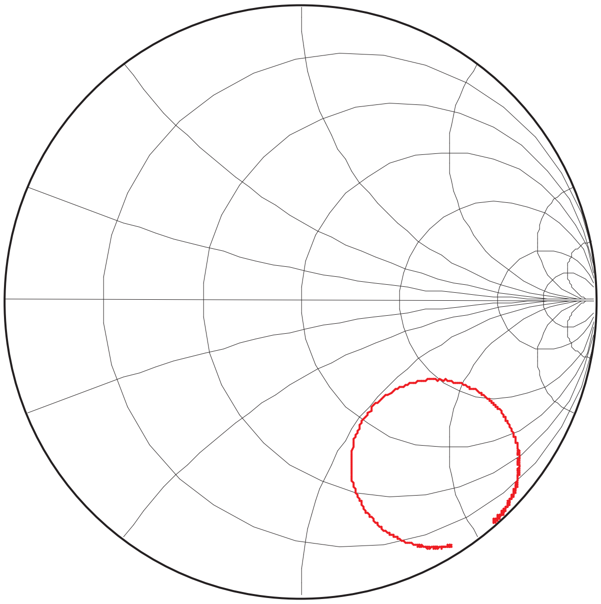
12.8 GHz Cavity Resonator



Resonant Frequency (GHz)	Temperature Coefficient of Frequency* Typical (ppm/°C)	Return Loss @ Resonance Typical (dB)	Loaded Q Typical (50 Ohms)	Dimensions	
				mm	inches
12.80	CF Material: - 2.3	-7	350	3.8 x 3.6 x 0.8	0.15 x 0.14 x 0.03

* over the range -20°C to +120°C



Dielectric Laboratories Inc.
2777 Route 20 East
Cazenovia, New York, USA
13035-9433
phone 315.655.8710
fax 315.655.0445
www.dilabs.com
email sales@dilabs.com
or europesales@dilabs.com
or asiasales@dilabs.com

Single Frequency Cavity Resonator™

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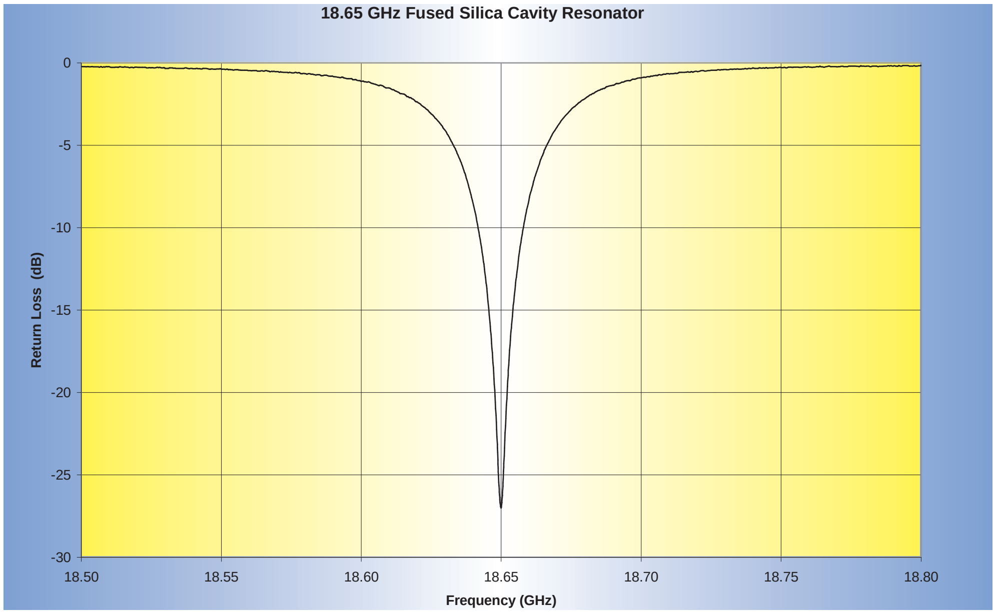
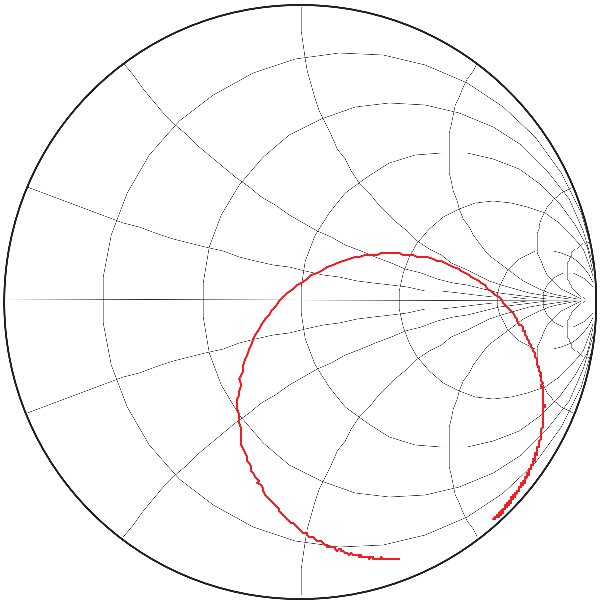
18.65 GHz Cavity Resonator

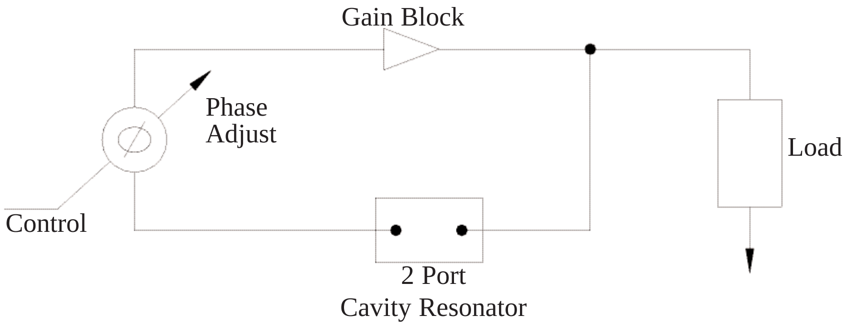


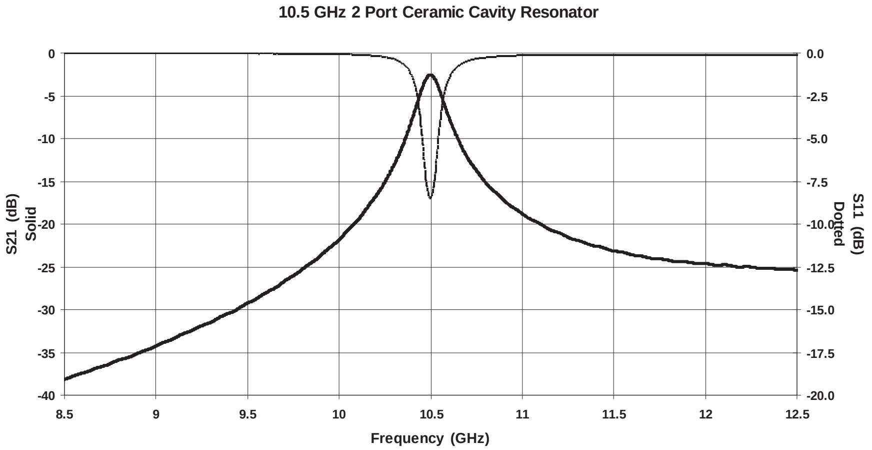
Resonant Frequency (GHz)	Temperature Coefficient of Frequency* Typical (ppm/°C)	Return Loss @ Resonance Typical (dB)	Loaded Q Typical (50 Ohms)	Dimensions	
				mm	inches
18.65	FS Material: - 7.3	< -25	400	6.1 x 5.6 x 1	0.24 x 0.22 x 0.04

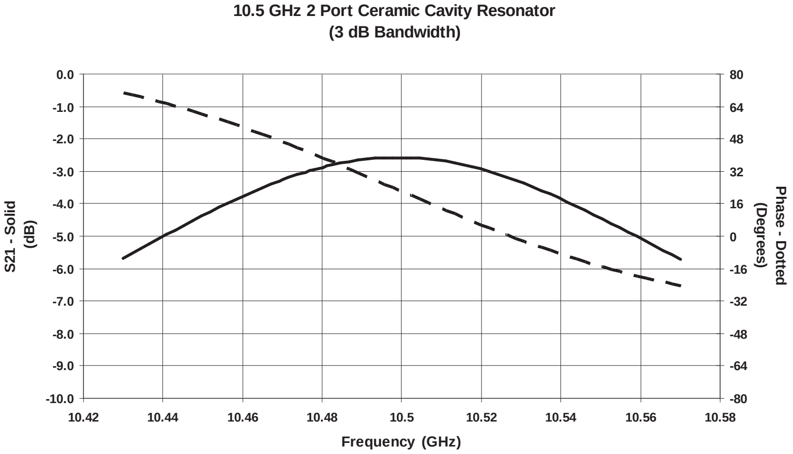
* over the range -20°C to +120°C



Narrow-Band Varactor Tuning of Cavity Resonators







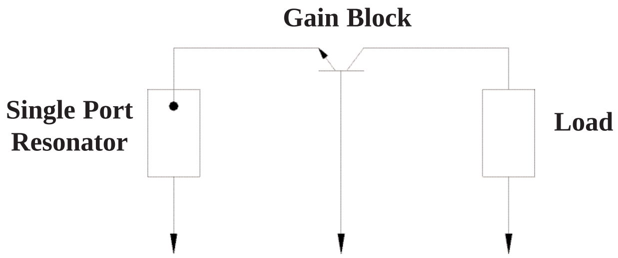
Consider a ceramic cavity resonator for your next oscillator design. The inherent stability of ceramic offers excellent long term aging performance and temperature stability. High loaded Q's promise excellent phase noise performance.

The use of a 2-port resonator for voltage controlled oscillator applications is represented by the loop model of the oscillator above. Frequency adjustment or modulaton is easily accomplished by the introduction of the voltage variable phase shifter. Typical broadband resonator performance and the amplitude (solid) and phase (dotted) variation of the 2-port resonator over the 3 dB bandwidth are illustrated to the left.

The inherently shielded nature of the ceramic resonator, its small size, and ease of mounting present many interesting miniaturization possibilities.

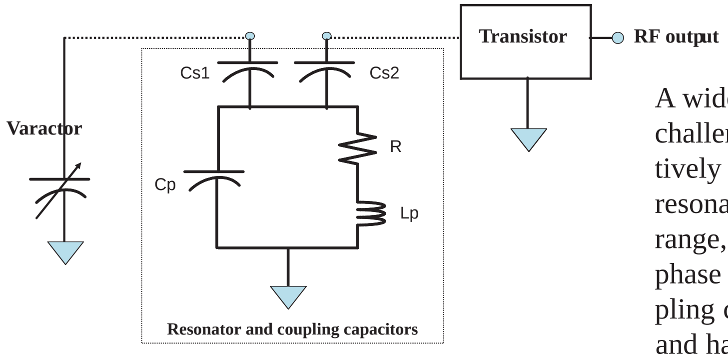
Dielectric Laboratories Inc.
2777 Route 20 East
Cazenovia, New York, USA
13035-9433
phone 315.655.8710
fax 315.655.0445
www.dilabs.com
email sales@dilabs.com
or europesales@dilabs.com
or asiasales@dilabs.com

Narrow-Band Tunable Resonator



Application of a 1-port resonator in a narrow-band or fixed frequency application is represented by the negative resistance model shown above.

Wide-Band Tunable Resonator

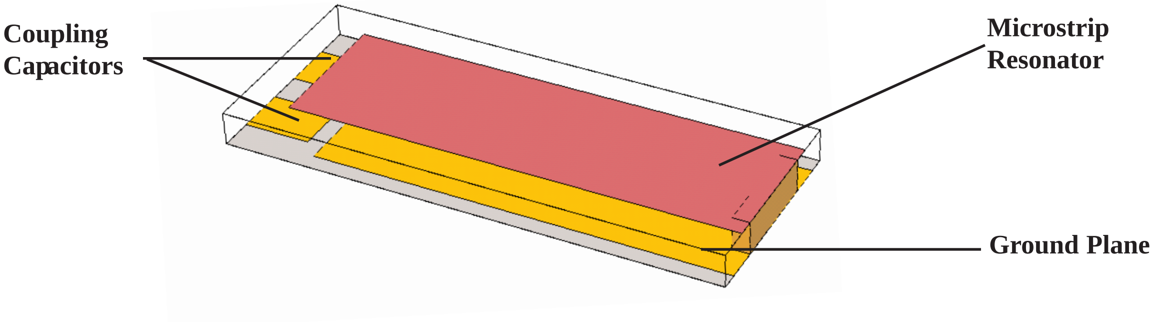


All connections on bottom side of network for SMT assembly

A wideband VCO at microwave frequencies can be challenging to design for good phase noise. The relatively poor varactor Q degrades the loaded Q of the resonant circuit, an effect which increases with tuning range, thus degrading phase noise. To achieve the best phase noise from the oscillator, the resonator and coupling capacitors must be high Q, temperature stable and have tight tolerance. This minimizes excess tuning range and maximizes loaded Q.

DLI's Wide-Band Tunable Resonator, illustrated in the see-through 3-D graphic below, is a precision surface mounted thin film microstrip resonator with integrated coupling capacitors. DLI's proprietary ultra-stable, Hi-Q, Hi-K ceramics are employed to provide optimum performance in a miniature size. A simplified oscillator circuit incorporating the Wide-Band Tunable Resonator with integrated coupling capacitors Cs1 and Cs2 is shown above.

In contrast, current designs frequently employ discrete resonators and surface mount capacitor chips (MLC) to provide the coupling capacitances. The tolerances of these discrete parts cause significant variations in VCO unit to unit performance. The MLCs have lower Q's and larger, undesirable parasitic inductance than DLI's integrated thin film coupling capacitors. The lower parasitic effects of the DLI thin film integrated design reduce spurious oscillations, improve tuning characteristics and can enable higher frequency operation.



TM

Cavity Resonator

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Designing a Custom Resonator

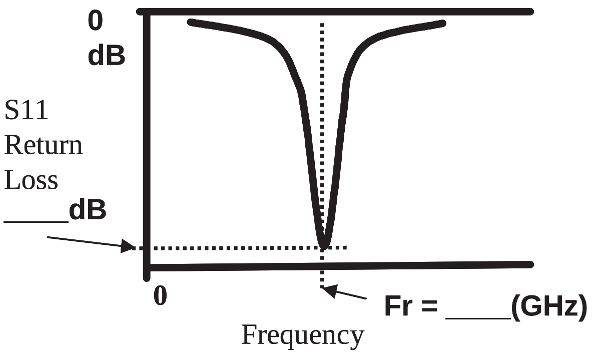
Custom Resonator Design

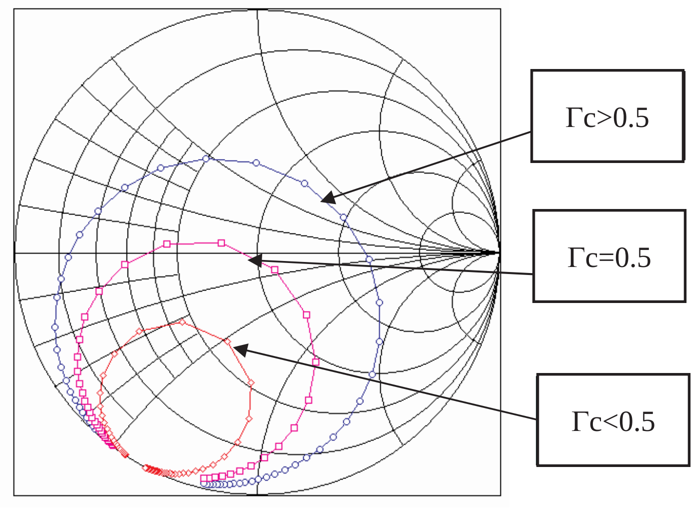
Design inputs:

1. Resonant Frequency, Fr
2. **One port Resonator:** Desired Return Loss (dB) at the resonant frequency (see Smith chart below)
3. Loaded Q objective
4. Case size restrictions
5. Mounting:
   A. SMT
   B. Epoxy & Wirebond
6. **Two port Resonator:** Maximum insertion loss at resonance

Frequency Response

(Return Loss versus Frequency)





With the impedance locus circle greater than 0.5, the return loss at resonance is reduced and greater tuning of resonant frequency with external elements is possible

With the impedance locus circle equal to 0.5, the resonator will exhibit excellent return loss at resonance.

With the impedance locus circle less than 0.5, the return loss at resonance is reduced and the effect of external circuitry on resonant frequency is reduced.

Case Size (inches)	Preferred (X,Y,Z):____________________ Maximum Length:________ Maximum Width:________ Maximum Thickness________
Fr Resonance Frequency (GHz)	Fr=_____________ Tolerance_________%
One Port Resonator: Return Loss (dB) @ resonant frequency, 50 ohm system	RL=___________dB, Nominal Γc<0.5_______ ---or----- Γc>0.5__________
Desired Loaded Q	QL=___________, Two Port QL=BW$_{3dB}$/Fr=________
Two Port Resonator: Maximum Insertion Loss at resonance	Loss, maximum= ___________dB
Frequency stability Operating Temperature range (C°)	ΔFr/ΔT=_______ppm/ °C Minimum Temperature: ________ Maximum Temperature:_______
Assembly **(SMT or Epoxy)**	Conductive Epoxy attach______ Solder attach______ Wire/ribbon bond______ Solder type________ Max. Process Temp. ____°C
Board Material	Material ________ Dielectric constant _______ Thickness_________