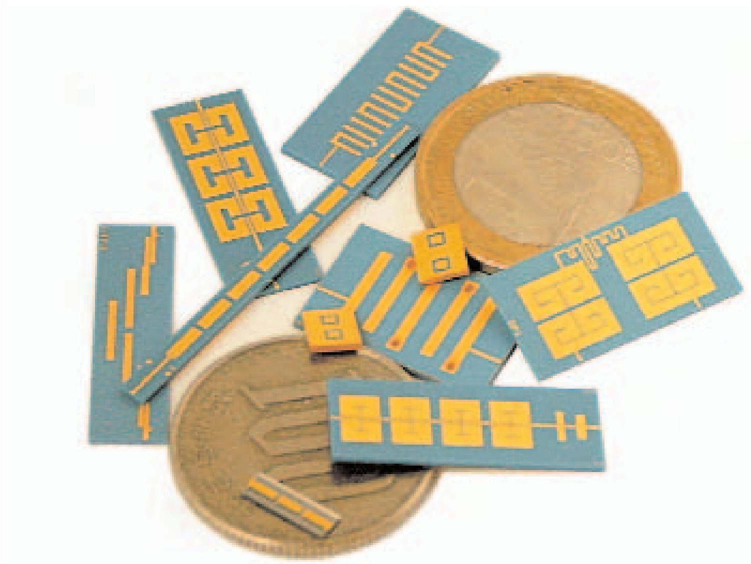
Resonators, Filters, and Custom Ceramic Components

Disruptive Technologies for Spectrum Management



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DIELECTRIC LABORATORIES
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Company Overview

Dielectric Laboratories Inc. (DLI) is your global partner for application specific microwave and millimeter-wave components serving customers in military, fiber optic, wireless, medical, transportation, semiconductor and avionics markets. With more than 30 years of experience, you can turn to DLI with confidence for your high frequency Single-Layer Capacitors, Multi-Layer Capacitors, Thin Film components, heat sinks, and custom microwave solutions.

DLI continues to introduce exciting new innovations in custom ceramic resonator and filter technologies. These new patent-protected products leverage decades of ceramic and thin film experience, creative and clever design expertise, and advanced prototyping and testing capabilities.

DLI is commited to serving you and thanks you for your business!

Quality and Environmental Policy

DLI's reputation for quality and environmental responsibility is based on a commitment to not only meet customer's requirements, but to exceed expectations. The entire organization, beginning with top management, strives to achieve excellence in designing, manufacturing and delivering capacitors and integrated thin film products for high frequency applications, while maintaining safe and healthy working conditions. Furthermore, DLI commits to achieve these goals in an environmentally responsible manner through our commitment to comply with environmental regulations and implement pollution prevention initiatives. DLI strives to continually improve the effectiveness of our Quality and Environmental Management Systems through the establishment and monitoring of objectives and targets.

DLI's quality system is certified to the ISO 9001:2000 international standards and its environmental system is certified to the ISO 14001:2000 international standards.

RoHS Compliance Statement

DLI is fully commited to offering products supporting Restriction of Hazardous Substances (RoHS) directive 2002/95/EC. All DLI dielectric formulations are RoHS compliant and the company offers a comprehensive range of ceramic components free of lead. DLI complies with the requirements of the individual customer and will maintain product offerings that meet the demand of our industry.

Premier Edition June 2005

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Introduction

DLI has built its global reputation as a manufacturer of high frequency, high Q capacitors. In recent years, DLI has emerged as a comprehensive manufacturer of specialty ceramic components for high frequency applications. With over three decades of material science formulation and development, more then one hundred proprietary and/or patented ceramic formulations, and multiple recent patent filings, DLI is the pre-eminent ceramic component manufacturer in the industry. The marriage of ceramic expertise, manufacturing know-how, product quality, customer service, product customization, and clever microwave and RF design engineering sets us apart from all others in the industry. This product brochure will introduce you to the unique disruptive technologies that have become part of the new DLI.

What Makes DLI Unique?

DLI has leveraged its materials, processes and engineering capabilities to produce unique products to complement the imagination of the electronic and scientific communities. DLI has more then 100 proprietary ceramic formulations offering K values from as low as 4 to more then 40,000. DLI's ceramic formulations can be used to custom match the Thermal Coefficient of Expansion (TCE) to the customer's implementation.

To highlight how our engineers can design terrific new products for our customers, please consider just one of many core proprietary materials. Our 'CF' material has these features:

- Temperature stability of ±15 ppm/°C vs. typical Alumina which has a temperature stability of +120 ±30 ppm/°C; an *8x* improvement.
- Miniaturization capabilities over typical Alumina or Printed Circuit board materials. Our CF offers a size reduction of *15x* compared to PWB materials and more then *2x* compared to Alumina.
- 'CF' does not exhibit signs of aging, having been used in our SLC and MLC Product Lines for decades.
- This material does not out-gas in a space environment because of the dense nature of the fired ceramic.

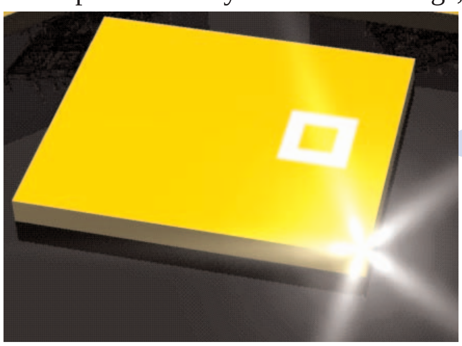
DLI gives its talented design engineers a broad set of proven materials on which to implement their revolutionary design ideas. *DLI redefines the envelope!*

Single Frequency Cavity Resonator™

Patent Pending

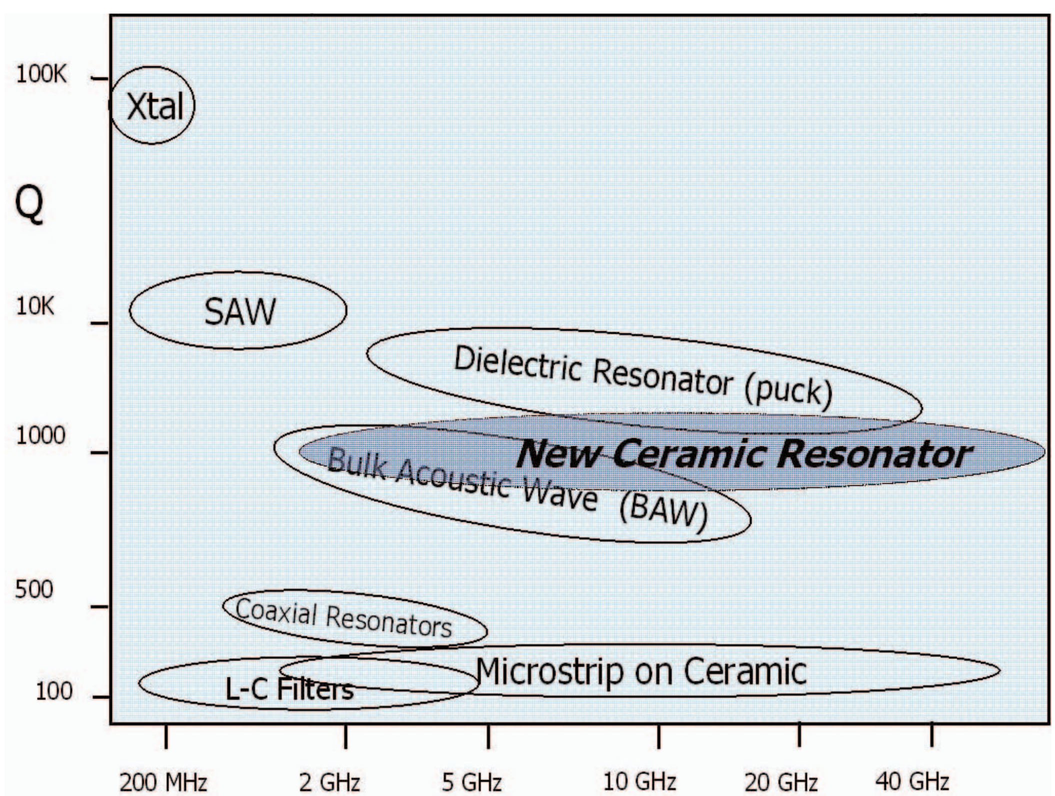
DLI's Cavity Resonators set a new standard for high Q resonator performance across a broad spectrum of frequencies. High Q resonators play a critical role in system noise performance, and employing this advantage is dramatically easier and less expensive than ever before. These products include extremely 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



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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)

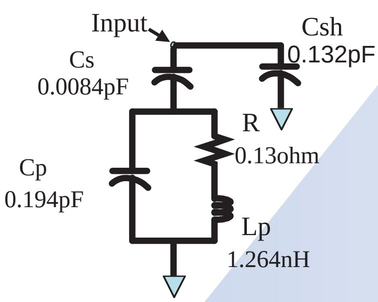
Comparison of a DLI 10 GHz Single Frequency Cavity Resonator (SFCR) With Competing Technologies

	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*	*$\sim 2x10^{-3}$*

Single Frequency Cavity Resonator™

Patent Pending

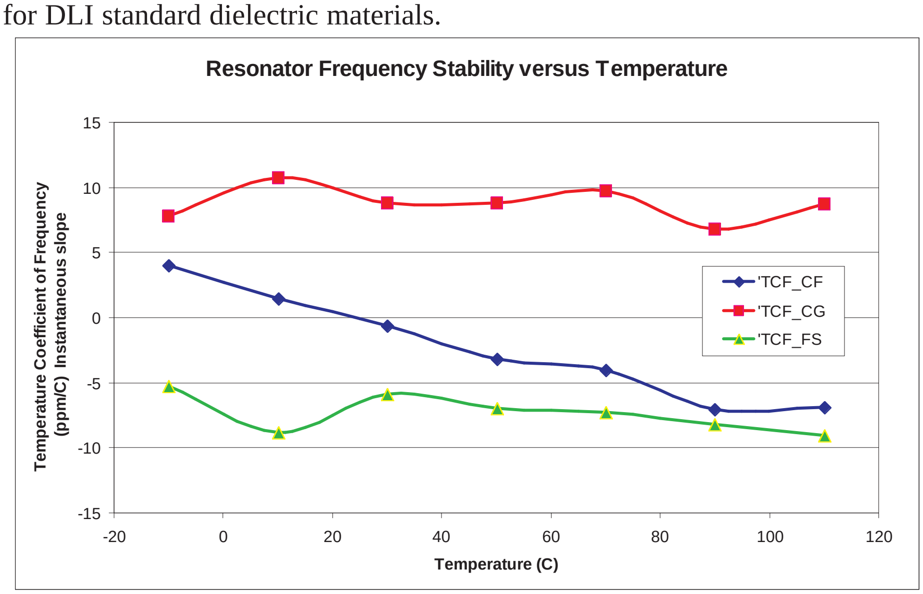
Part Identification Number					
ACR	**08250**	**CF**	**1**	**S**	**T**
Product Family	Resonant Frequency	Material Code	Frequency Tolerance	Mounting Code	Package
	GGmmm	CF, CG, FS	1= ± 0.1%	S=Surface Mount (SMT)	T=Tape/Reel
	Example:		2= ± 0.2%	W=Microstrip Mount	P= Waffle Pack
	08250=8.25 GHz		3= ±0.5%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



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.



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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

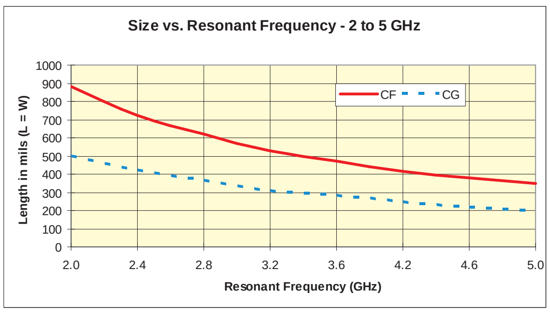
Resonant Frequency (GHz)	Temperature Coefficient of Frequency* Typical (ppm/°C)	Return Loss @ Resonance Modeled (dB)	Loaded Q Modeled (50 Ohms)	Dimensions L x W x T	
				mm	inches
3.2	CG Material: 8.8	-22	290	8.1 x 8.1 x 3	0.32 x 0.32 x 0.1 2
5.0	CF Material: - 2.3	-12	550	8.1 x 8.1 x 3	0.36 x 0.36 x 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

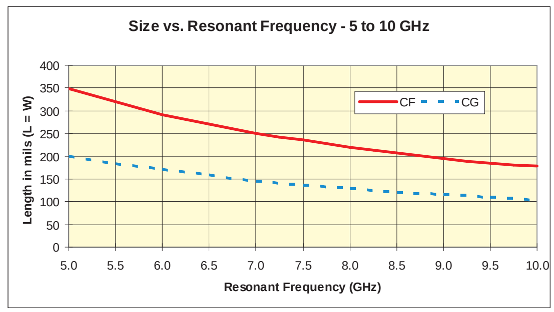
* over the range -20°C to +120°C

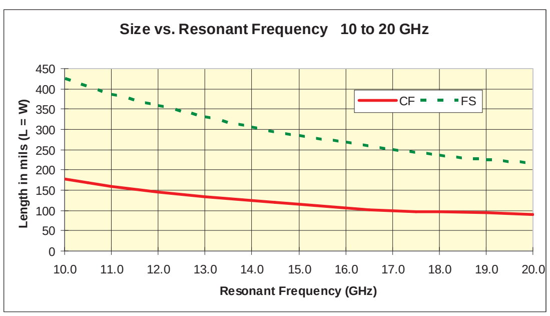
Estimating Resonator Size

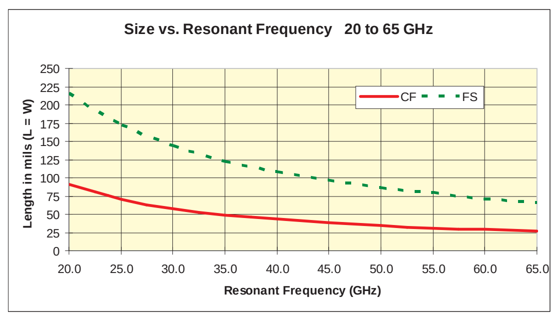
The size of the Cavity Resonator is determined by the desired resonant frequency and the ceramic material selected. Generally, for a given frequency resonator, selecting material types which result in larger part size also result in higher Q resonators. Increased resonator height also enhances Q. For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

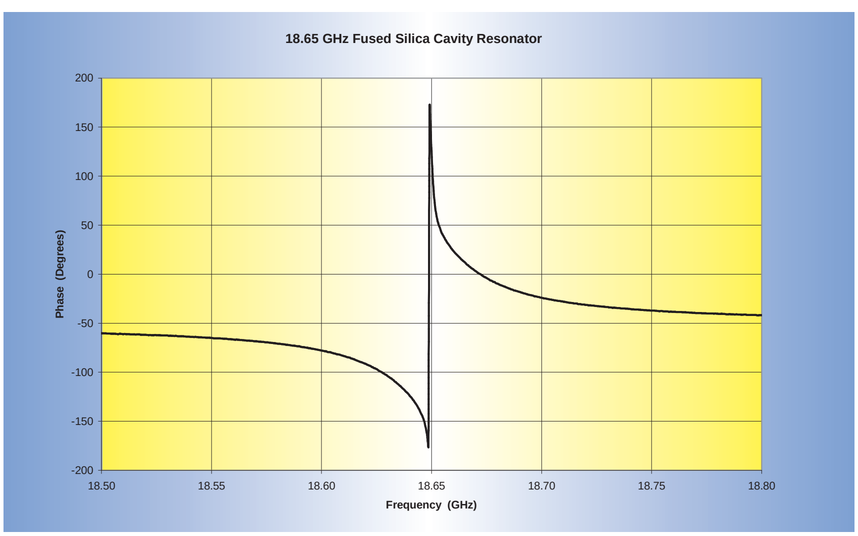
The charts on this page should be used as a guide for selecting the ceramic materials to be used and to closely estimate the resonator length dimension for a square device. Typical designs are nominally rectangular, with length to width aspect ratios of less than 1.2:1.











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.

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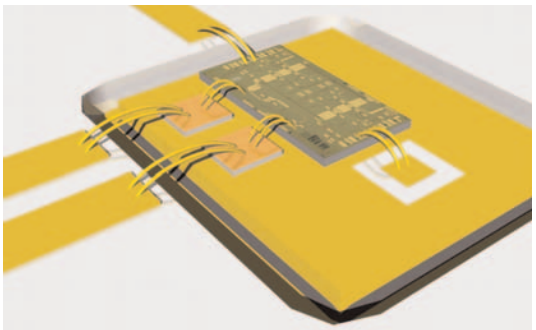
Mounting Alternatives



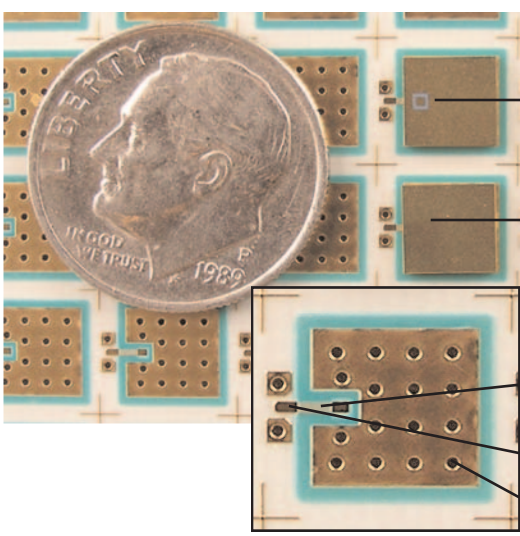
Microstrip Mount

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 Epo xy	Nickel/Gold	Nickel/Gold
Microstrip Mount W	Component to Substrate Interface	Conductive Epoxy	Gold	-
	Input/Output Interconnect	Thermocompression - Wirebond	-	Gold

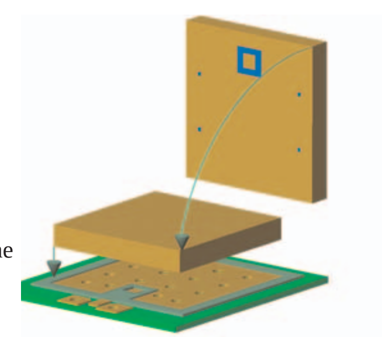
For more information on metallization codes, see page 19



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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Single Frequency Cavity Resonator

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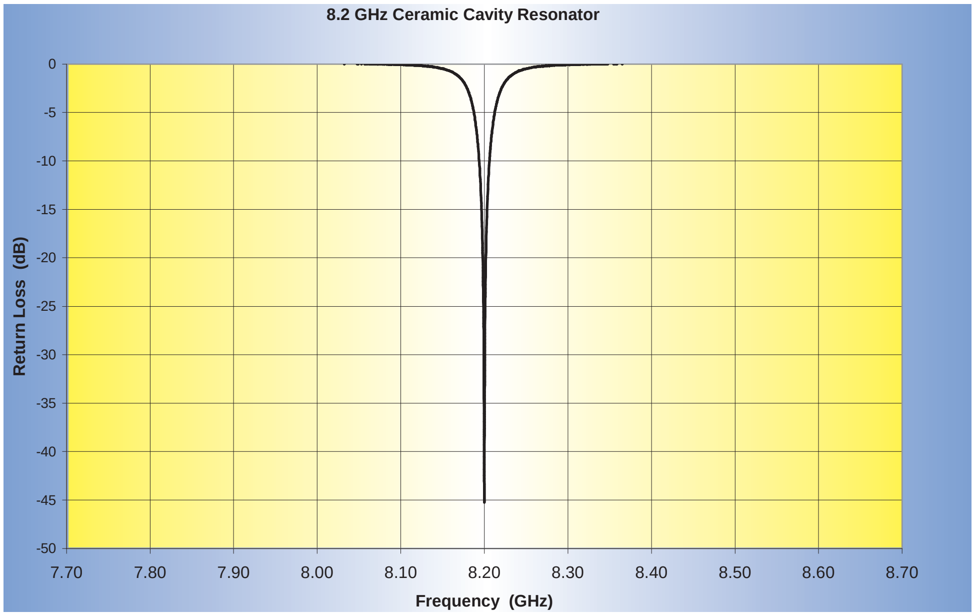
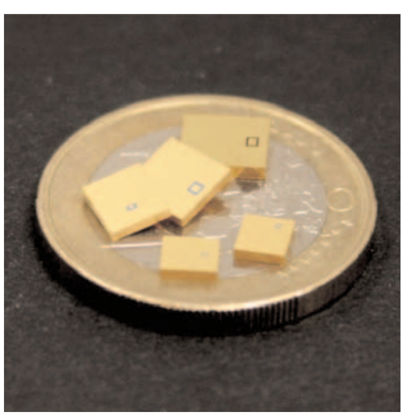
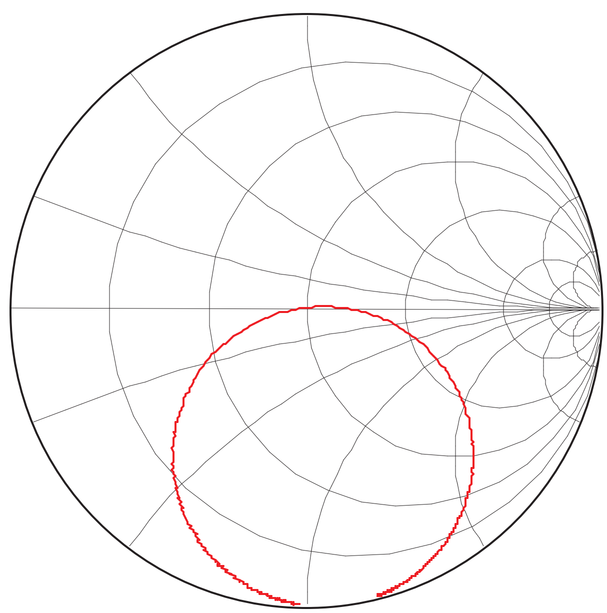
8.2 GHz Cavity Resonator



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





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Single Frequency Cavity Resonator

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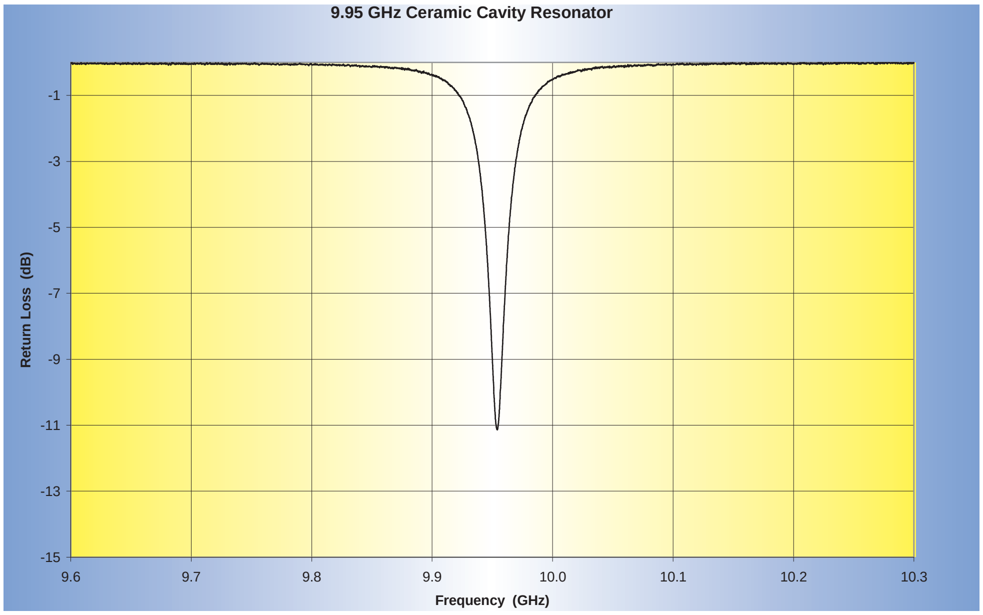
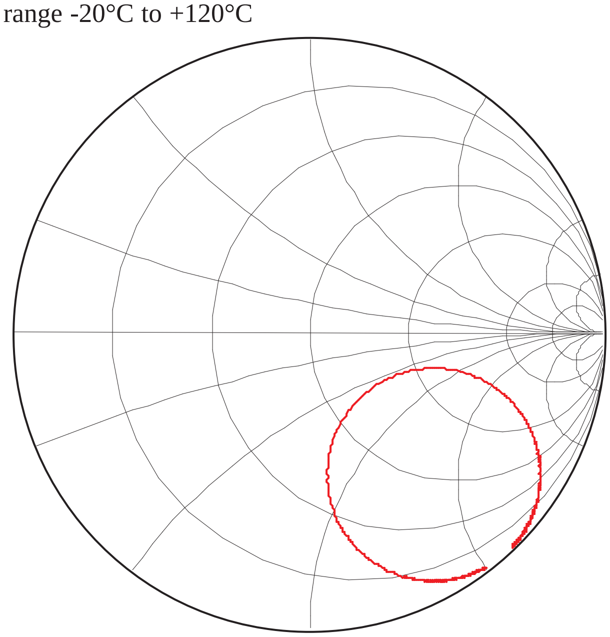
9.95 GHz Cavity Resonator

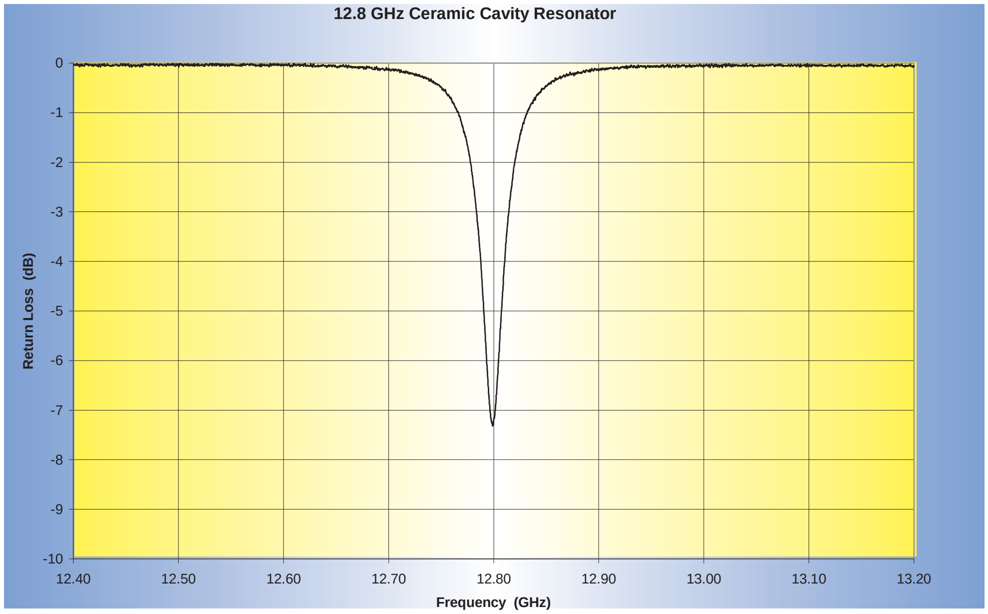


Resonant Frequency (GHz)	Temperature Coefficient of Frequency* Typical (ppm/°C)	Return Loss @ Resonance Typical (dB)	Loaded Q Typical (50 Ohms)	Dimensions	
				mm	inches
9.95	CF Material: - 2.3	-11	300	5.6 x 4.3 x 0.8	0.22 x 0.17 x 0.03

* over the range -20°C to +120°C

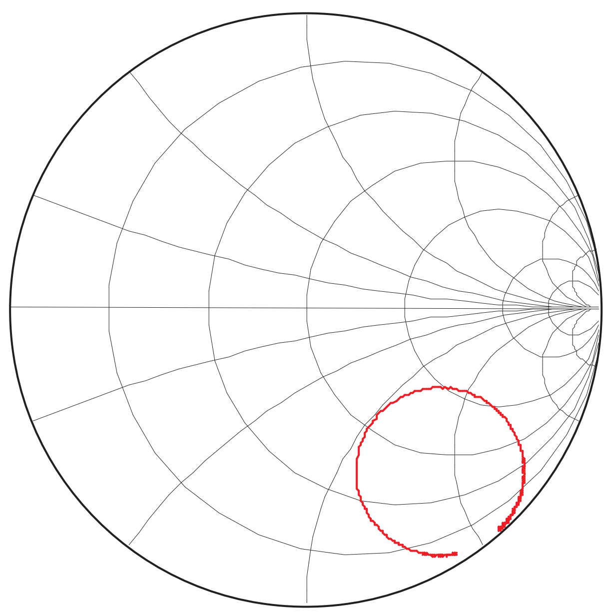


12.8 GHz Cavity Resonator



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



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Single Frequency Cavity Resonator™

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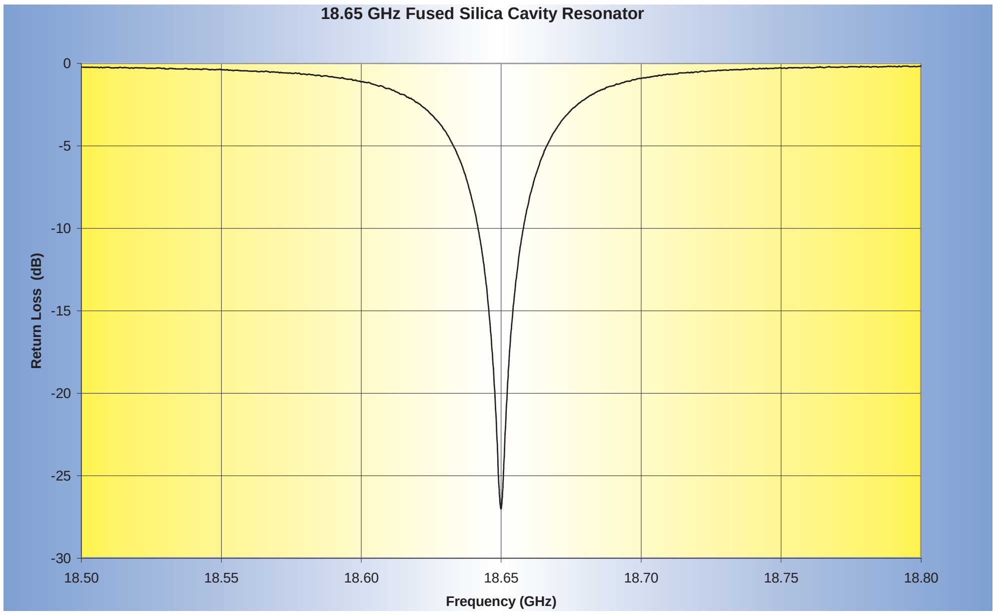
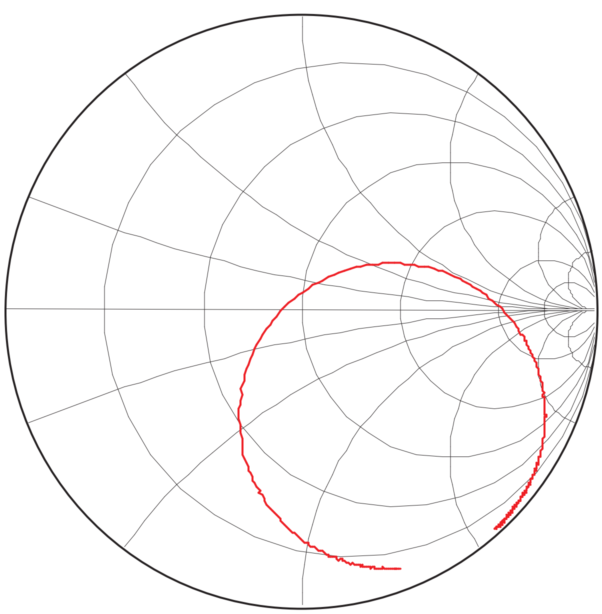
18.65 GHz Cavity Resonator

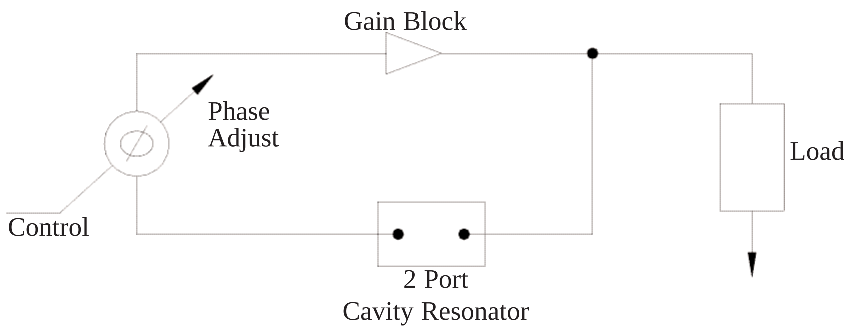


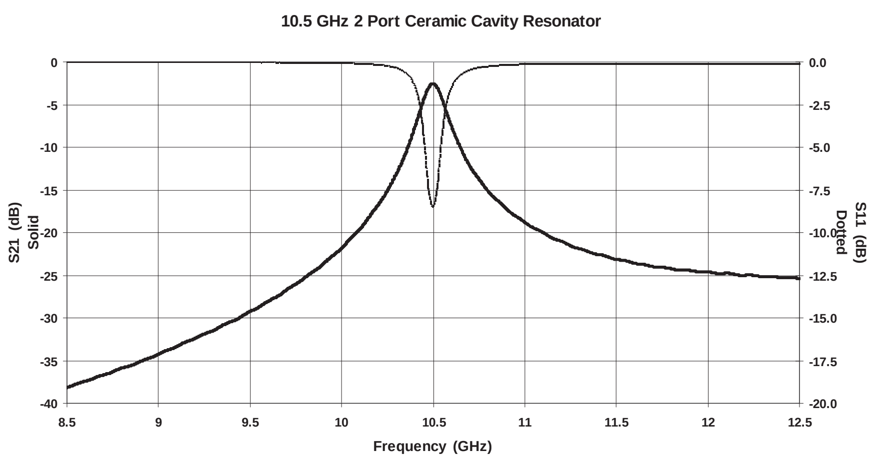
Resonant Frequency (GHz)	*Temperature Coefficient of Frequency* Typical (ppm/°C)*	*Return Loss @ Resonance Typical (dB)*	*Loaded Q Typical (50 Ohms)*	*Dimensions*	
				mm	*inches*
18.65	FS Material: - 7.3	< -25	400	6.1 x 5.6 x 1	0.24 x 0.22 x 0.04

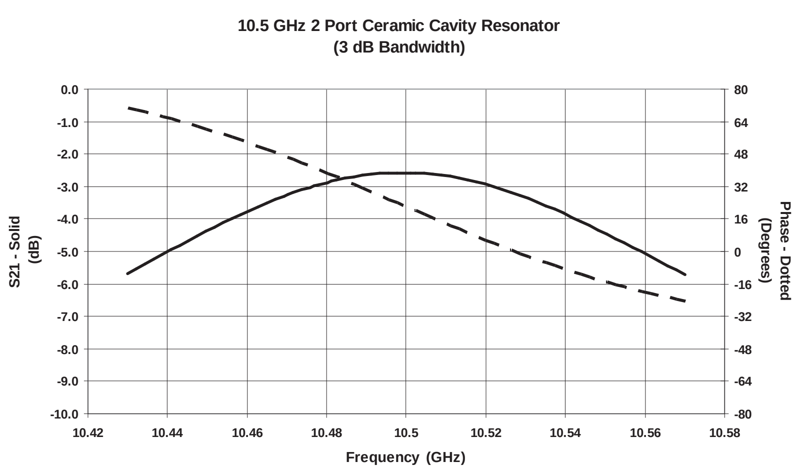
* over the range -20°C to +120°C



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.

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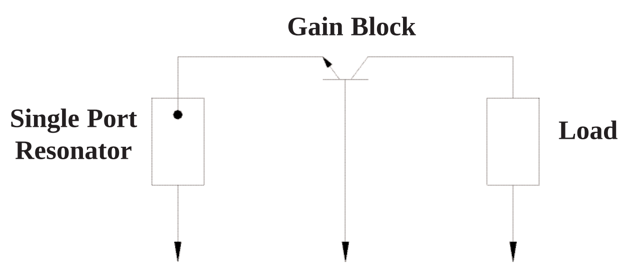
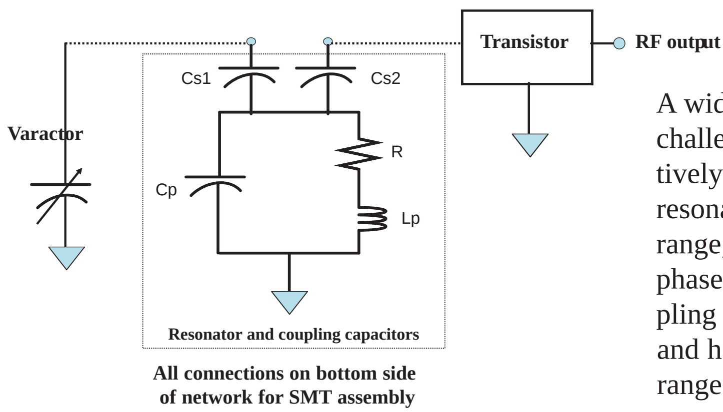
Narrow-Band Tunable Resonator



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

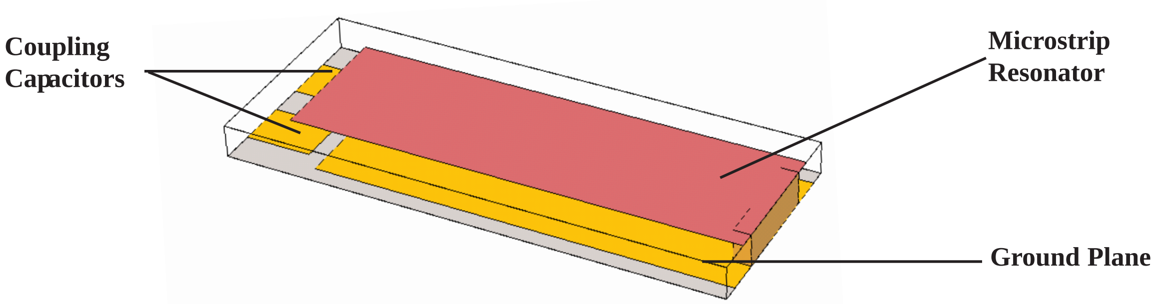
Wide-Band Tunable Resonator



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.



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TM
Cavity Resonator
Patent Pending

XTREME-Q

Designing a Custom Resonator

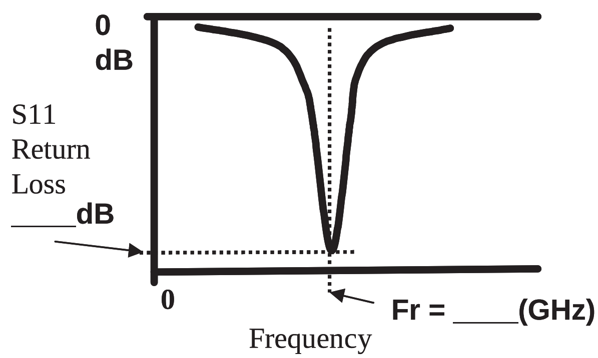
Custom Resonator Design

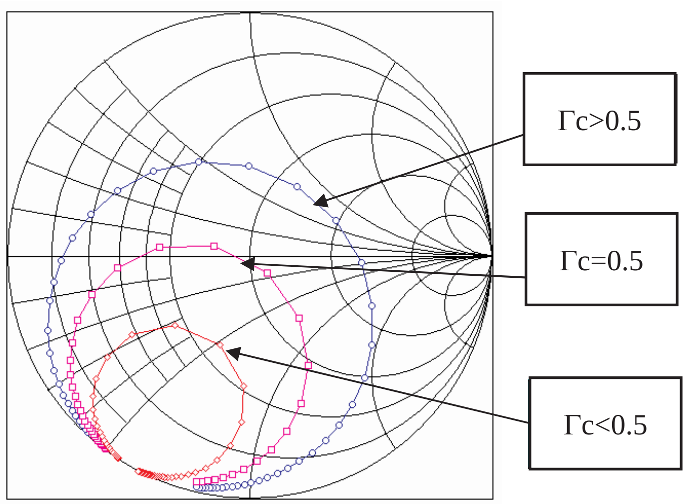
Design inputs:

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_________

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Self Bias Network

For self biased MIC GaAs Fet amplifiers, this device integrates source decoupling and user selectable bias resistance

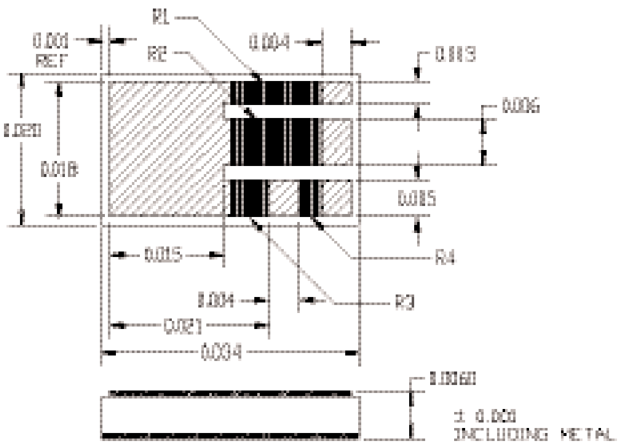
Functional Applications

- Wireless communication modules
- MIC broadband high gain RF/Microwave modules
- Bias line voltage divider and integrated decoupling capacitor

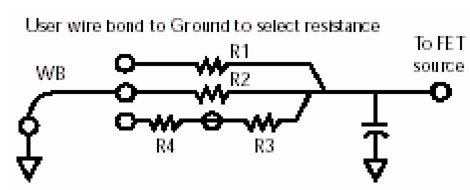
Benefits

- Improves gain flatness and stability in GaAs FET amplifiers
- Simplifies assembly with one component
- Miniature size :.020" x .034" (.5mm x .86mm)

Physical Characteristics



Equivalent Schematic Representation



Resistor Values:
R1 - 200Ω
R2 - 100Ω
R3 - 50Ω
R4 - 20Ω

Nominal Capacitance:
50pF

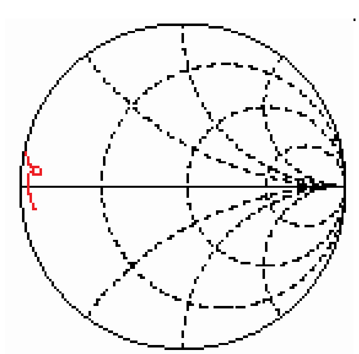
Typical application requires 2 networks

Recommended Mounting: The Self Bias Network should be mounted with fully metalized side down directly on the RF ground plane for best performance

Product Number Identification

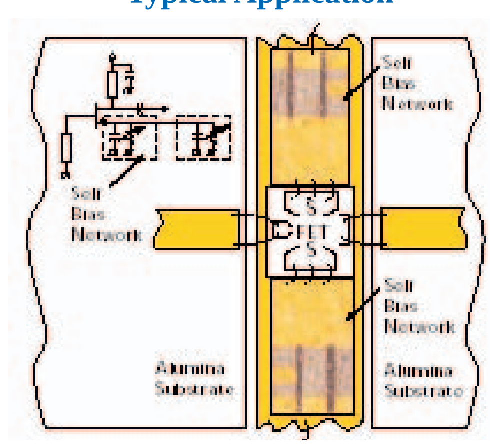
B	20	BH	SBN01
Product B = Bias Network	**Width** 28	**Material** BH ± 15% TC BT +22,-56% TC	**Network Type**

Physical Characteristics



Typical S11
Frequency Range: 1.0 to 20 GHz
Reflection Coefficient: 50Ω Normalized

Typical Application



Custom Networks can be designed per customer specification. Please consult Factory for additional information or special requirements.

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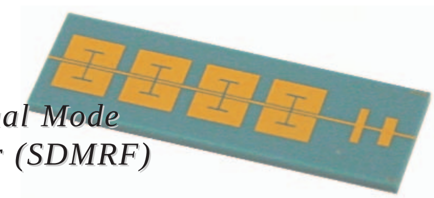
XTREME-Q

Miniature Ceramic Filters™

High Performance Filters from DLI

Typical Specifications

- Frequencies from 1 to > 67 GHz
- Insertion Loss ~ 2dB
- Return Loss 15 dB typical
- Rejection 45 dB typical
- Pass band Width <15%



Symetrical Dual Mode Resonator Filter (SDMRF)

Demonstrated capability of high frequency filter designs

- Lowpass, Highpass, and Bandpass
- Designs include:
  - Tchebyshev
  - Bessel cross-coupled responses in various topologies
  - Resonators (e.g. Ring and Dual mode)
  - Edge Coupled
  - End Coupled
  - Hair-Pin
  - Interdigitated
  - Custom Variants

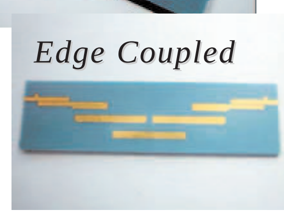
DLI Variant on Hair-Pin

Interdigitated

Hair-Pin

Advantages of DLI Hi K materials for Microstrip Filters

- Temperature Stability: 8 fold improvement with CF material
- Filter size reduction: 1/15th the area of PWB materials
- High repeatability
- Reduced size & cost systems



Edge Coupled

End Coupled

Typical Filter Specifications

Center Freq FC (GHz)	Material Code	3dB Bandwidth (MHz)	Filter Type	# of Poles	Passband Insertion Loss (dB)	Low Side -40 dB Point (GHz) (1)	High Side -40 dB Point (GHz) (1)	Mounting Code (2)	Length inches (mm)	Width inches (mm)
2.14	CF	350 (16%)	Interdig	7	1.8	1.80 (3)	2.36 (3)	S	0.740 (18.8)	0.400 (10.2)
3.5	CF	165 (5%)	SDMRF	12	2.5	3.08	3.9	M	0.900 (22.9)	0.330 (8.4)
4.2	CF	250 (6%)	SDMRF	12	2.4	3.63	4.72	M	0.900 (22.9)	0.330 (8.4)
5.6	CF	410 (7%)	Edge Cpl	5	2.2	5.21	6.13	M	0.925 (23.5)	0.260 (6.6)
6	CF	590 (10%)	SDMRF	16	3.7	5.62	6.53	M	0.700 (17.8)	0.330 (8.4)
6.5	CF	390 (6%)	SDMRF	16	2.7	5.96	7.24	M	0.700 (17.8)	0.330 (8.4)
9.7	CF	420 (4%)	End Cpl	7	2.9	9.36	10.04	M	1.500 (38.1)	0.100 (2.5)
37	FS	760 (2%)	End Cpl	3	2.2	34.83	39.67	M	0.325 (8.3)	0.100 (2.5)

Note 1 : higher rejection can be achieved with a cover.
Note 2 : see definition of mounting codes on adjacent page.
Note 3 : data shown for this filter is for -30 dB point.

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XTREME-Q

Miniature Ceramic Filters™

DLI DIELECTRIC LABORATORIES A DOVER COMPANY

Part Number Identification					
AFL	**06000**	**B300**	**S**	**P**	**-xxxx**
Product Family	Center Frequency GGmmm Example: 06000=6.00GHz	Bandwith mmm B300=300MHz	Mounting Code S,W,M (see below)	Package T= Tape/Reel P=Tray	Drawing #

Filter Mounting, Interconnection and Metallization Schemes

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

Mounting Codes and Metallization

S Surface Mount - Conductive epoxy or solder mount.
Nickel/Gold on the top and bottom surfaces of the device.
Nickel Metallization: 20 micro-inches typical.
Gold Metallization: 5 to 20 micro-inches typical.
For solder applications gold is held to a minimum to prevent embrittlement in the solder system.

W Microstrip Mount - Wirebond Interconnection - Conductive epoxy mount.
Gold on the mounting surface and Gold on the top surface.
Gold Metallization: 50 micro-inches minimum, 100 micro-inches typical.

M Microstrip Mount - Wirebond Interconnection - Conductive epoxy or solder mount.
Nickel/Gold on the mounting surface and Gold on the top surface.
Nickel Metallization: 20 micro-inches typical.
Gold Metallization Bottom Surface: 5 to 20 micro-inches typical.
For solder applications gold is held to a minimum to prevent embrittlement in the solder system.
Gold Metallization Top Surface: 50 micro-inches minimum, 100 micro-inches typical.

For customized metallization systems - consult factory.

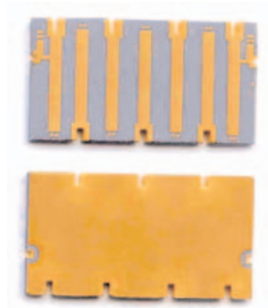
Ceramic Microstrip Filters

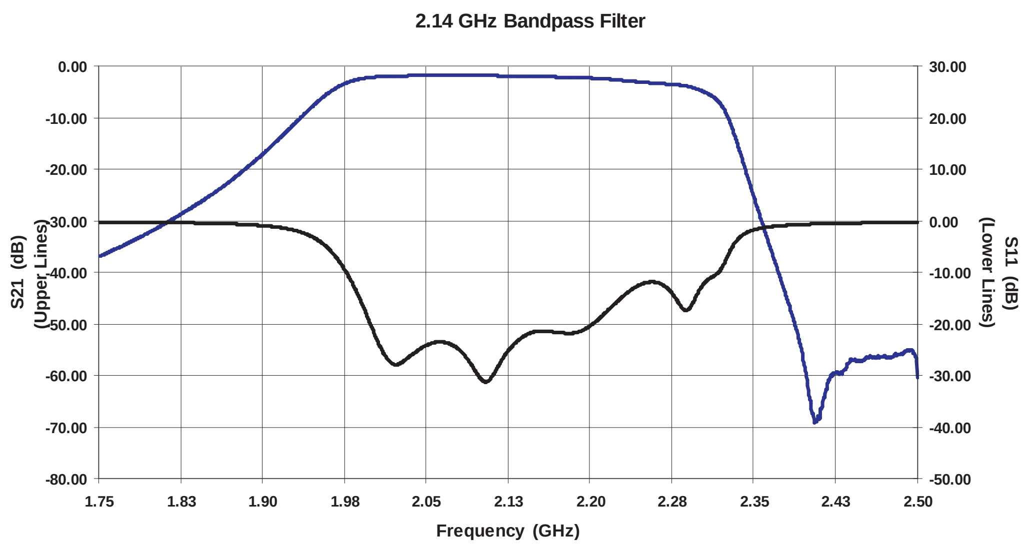
XTREME-Q™

2.14 GHz Bandpass Filter

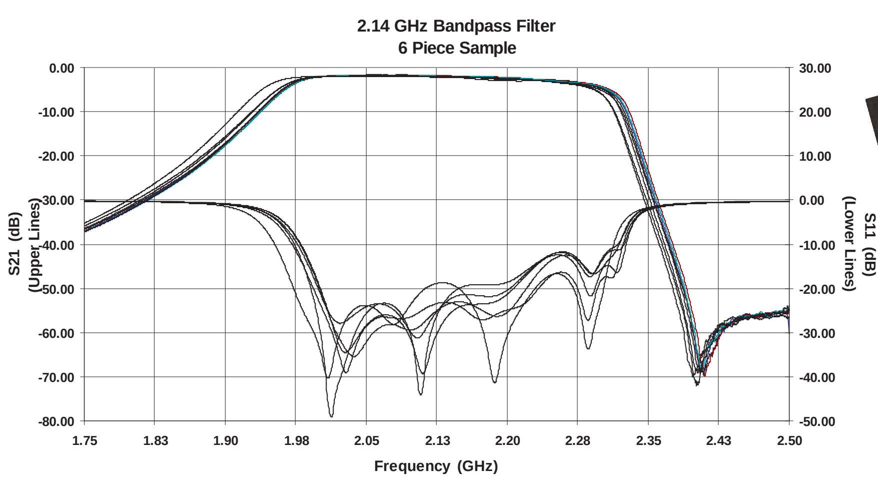
Unique Features

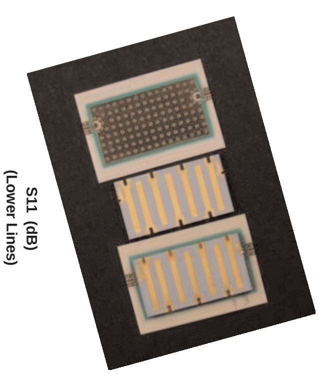
- 7-Pole Tchebyshev on K=23 ceramic
- Low loss: 1.8dB typical
- Temperature stable +/- 15ppm/°C
- Surface mountable
- Small size: 0.4 x 0.75 x 0.035 inches
- No tuning
- Good cost/size/performance tradeoff





The plot below illustrates filter performance repeatability in a surface mount comfiguration. Multiple devices fabricated on a single substrate, stringent material controls and precise processing enable excellent part repeatability at the lowest cost possible.





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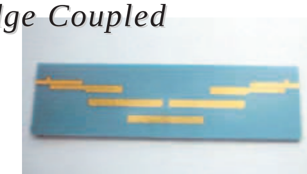
5.6 GHz Bandpass Filter

Edge Coupled



Hair-Pin

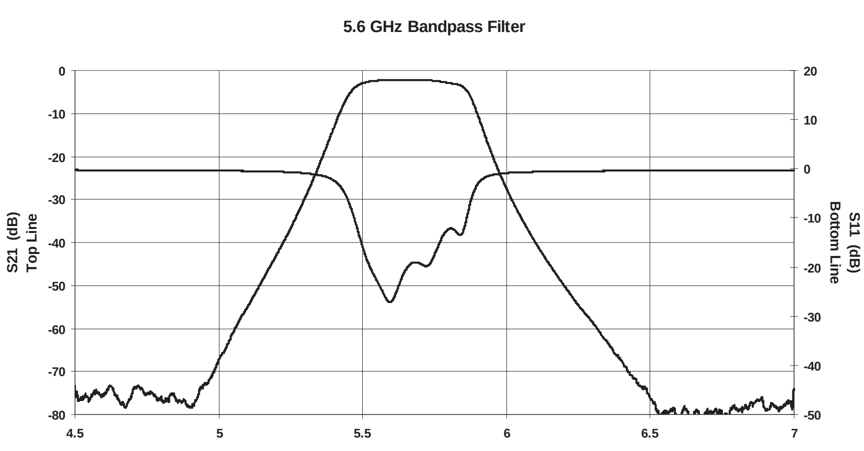
Ring Resonator

DLI's engineers select from numerous filter topologies to solve your frequency management problem. Size, cost, and performance tradeoffs are considered. Whether you have a new requirement or are trying to architect a topology to fit an existing slot, consider a ceramic solution.

Classical filter topologies can yield excellent performance in a small footprint when fabricated on ceramic substrate materials. Miniaturization reaches new levels by employing DLI high-k ceramic formulations. Different techniques of placing the resonant structures are observed in the accompanying photographs. Lower frequency implementations rely on folded resonators whereas high frequency designs generally use end coupled designs. Coupling is managed to yield the desired pass band/reject band performance. The correct placement of the input/output structures manage the impedance of the structure.

Performance requirements are easily converted to an implementation with the aid of classical modeling tools. The final physical implementation is verified using electromagnetic simulators and DLI proprietary software. Design and prototype time is minimized.

5.6 GHz Edge Coupled Bandpass Filter

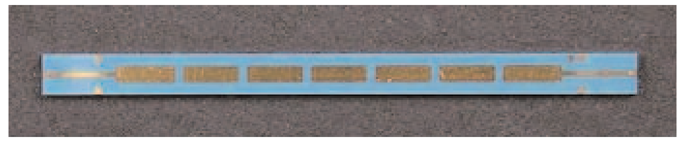


Ceramic Microstrip Filters™

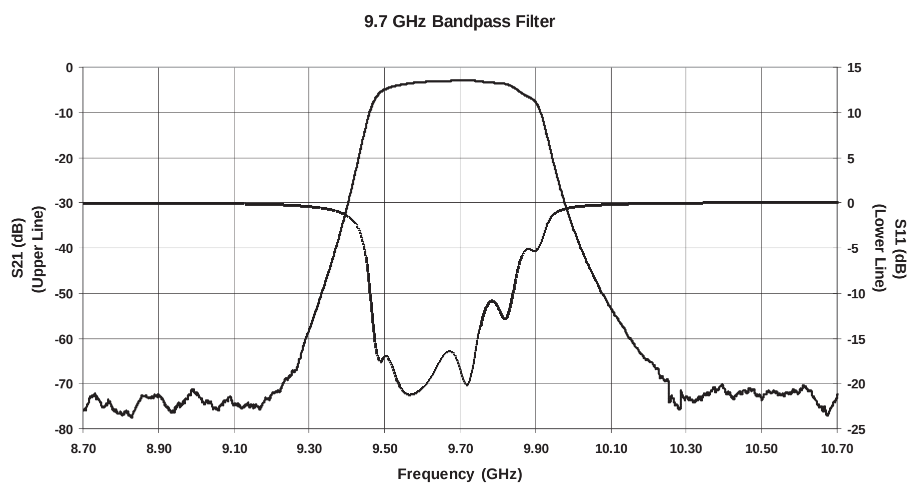
XTREME-Q

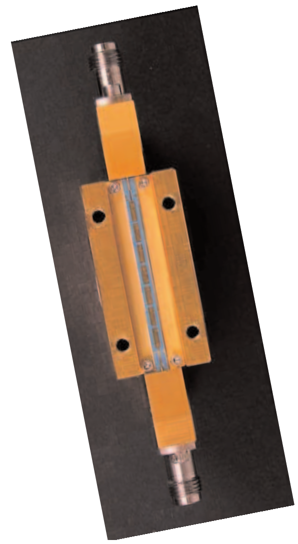
9.7 GHz Bandpass Filter

- 7-Pole End Coupled Filter
- 4% Bandwidth (400 MHz)
- Insertion Loss < 2.7dB
- Manufactured on CF Material, K=23
- Small size (1.1”x0.1”x0.03")

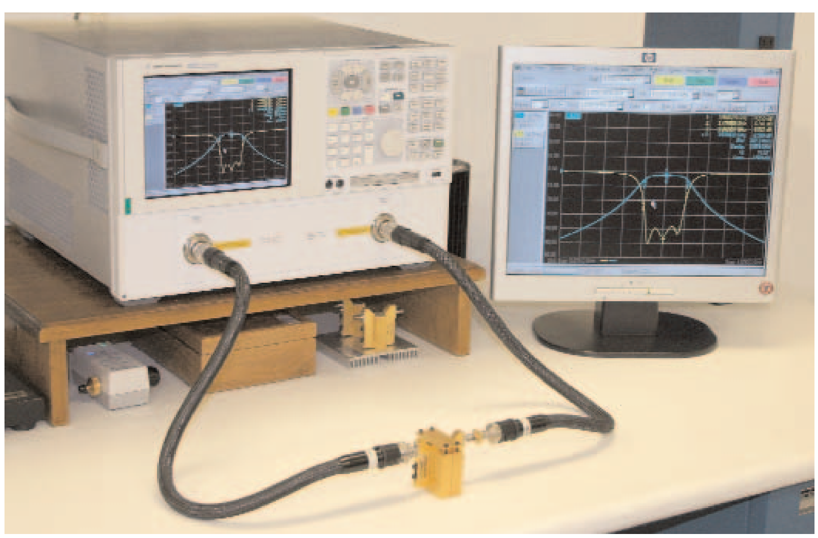


Measured Response of Filter in Fixture





The End Coupled resonator topology employed here is well suited for low percentage bandwidths (typically in the 2~5% range) and high out of band rejection. The 9.7 GHz filter is pictured both individually and attached to a carrier, which enables screw assembly and form /fit /function substitution for a larger more costly alternative. DLI’s high K material is utilized here for size and weight reduction. In a typical application conductive epoxy attachment to the floor of a channeled shield housing would be employed. With proper shielding, very high levels of rejection are possible. Approximately 70 dBc was achieved in this design. If designed for printed circuit materials the performance and repeatability would be inferior, and the filter length would be over 3 inches.



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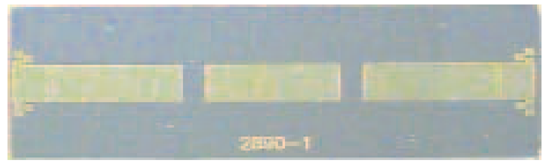
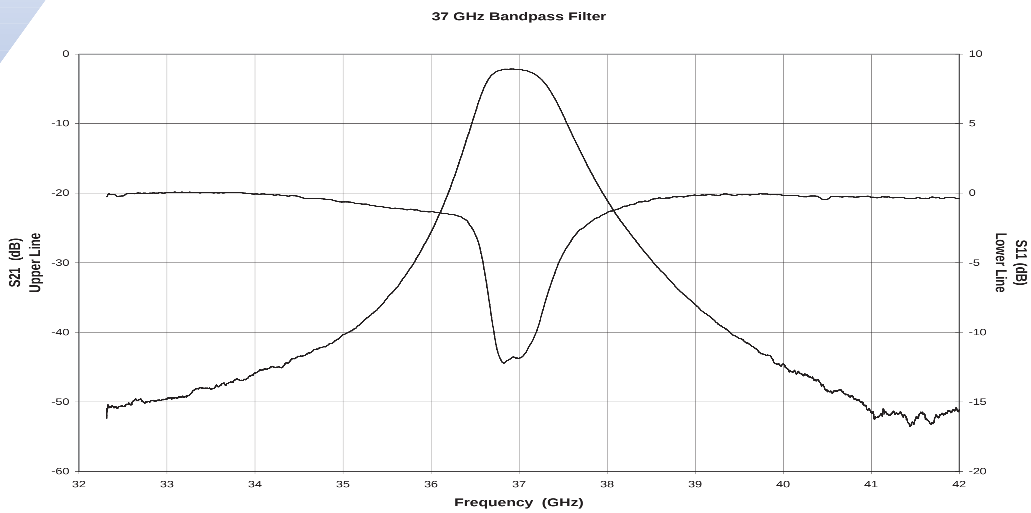
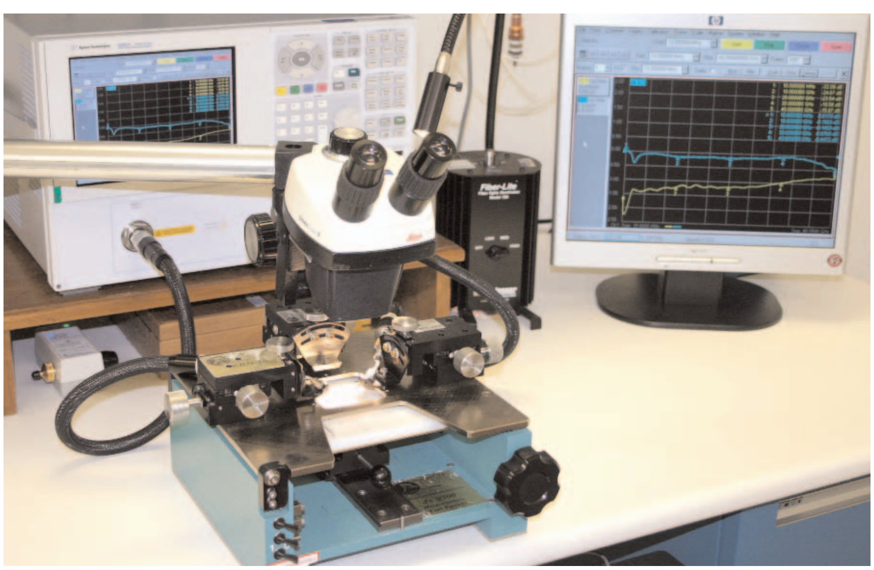
37 GHz Bandpass Filter

- Thin Film Gold on Fused Silica
- 3-Pole End-Coupled Tchebyshev
- 600 MHz Band-width (1.6% BW)
- <2.2 dB Insertion loss
- Size: 0.32 x 0.10 x 0.01 inches





The End Coupled resonator topology is applied to this 2% bandwidth filter. The narrow width (0.100 inches) of this filter design facilitates high isolation by enabling a below waveguide cut-off shielded housing. In a typical application conductive epoxy attachment to the floor of a channeled shield housing would be employed. Precision photolithography enables excellent unit to unit repeatability at low cost. DLI has precision measurement capability up to 67 GHz with the Vector Network Analyzer shown below. Both fixture and RF coplanar probe testing are employed, depending on the application.

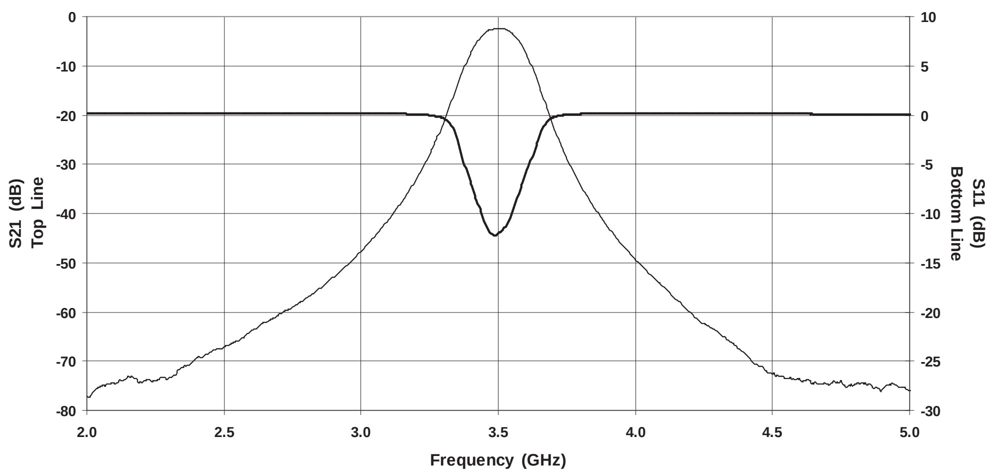


Miniature 12 and 16 Pole Bandpass Filters

Symmetrical Dual Mode Resonators
- High selectivity
- Low Insertion Loss
- Compact size

High K ceramic
- Miniaturization
- Temperature stable
- Hi-Q (low loss)

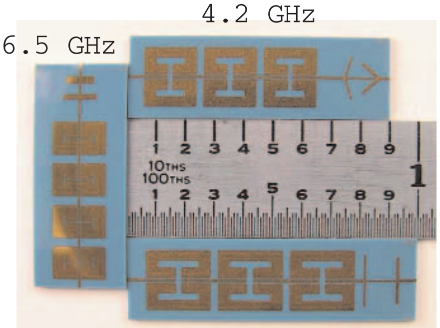
3.5 GHz Dual Mode Bandpass Filter



Applications for Dual Mode Resonator Bandpass Filters

The small size, low insertion loss and the sharp cutoff of the dual mode bandpass filters make then ideal for:
- Communications Receivers RF and IF Applications
- Frequency Synthesizer and Oscillator Applications
- Instrumentation
- RADAR Applications

4.2 GHz
6.5 GHz



3.5 GHz

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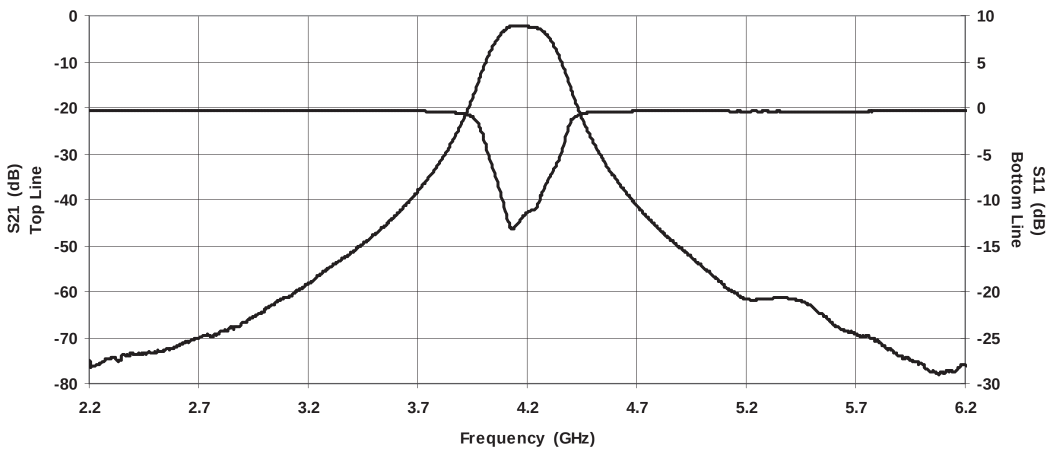
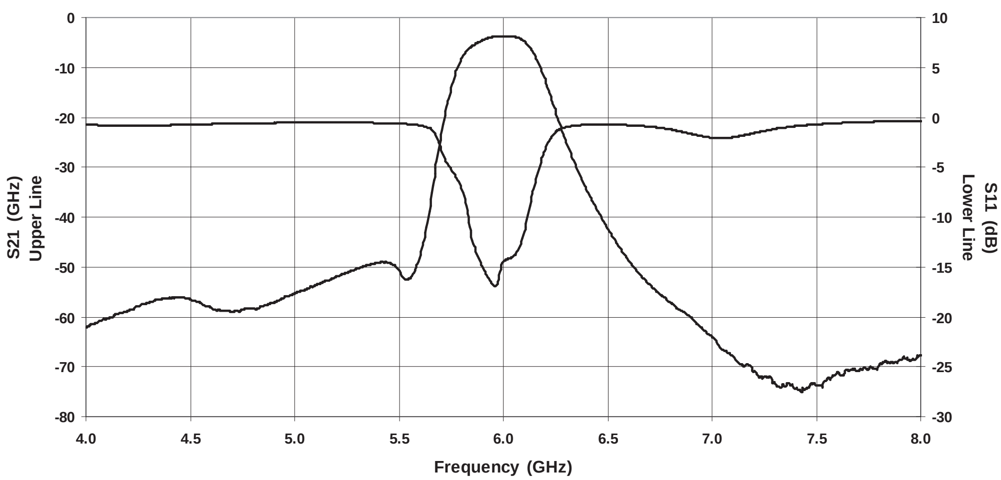
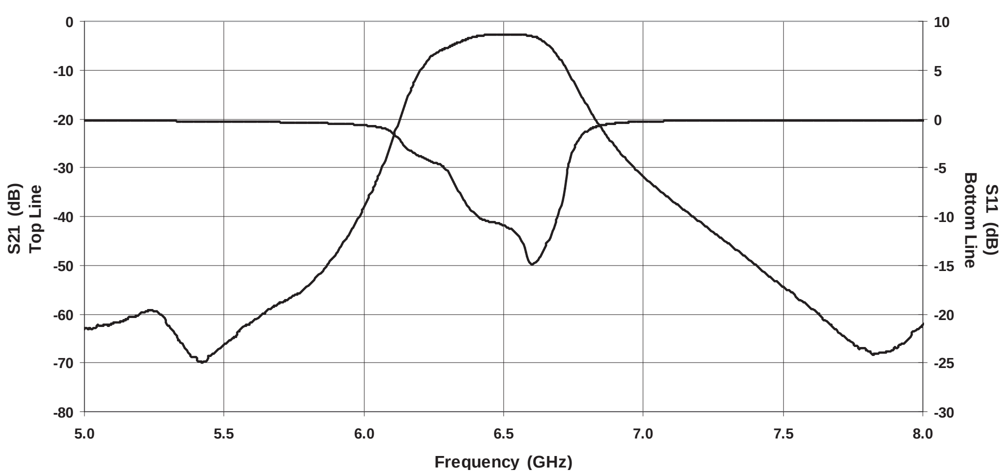
4.2 GHz Dual Mode Bandpass Filter



6 GHz Dual Mode Bandpass Filter



6.5 GHz Dual Mode Bandpass Filter

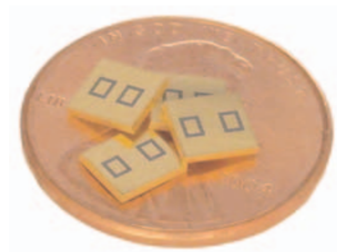


XTREME-Q™ **Ceramic Cavity Filters**

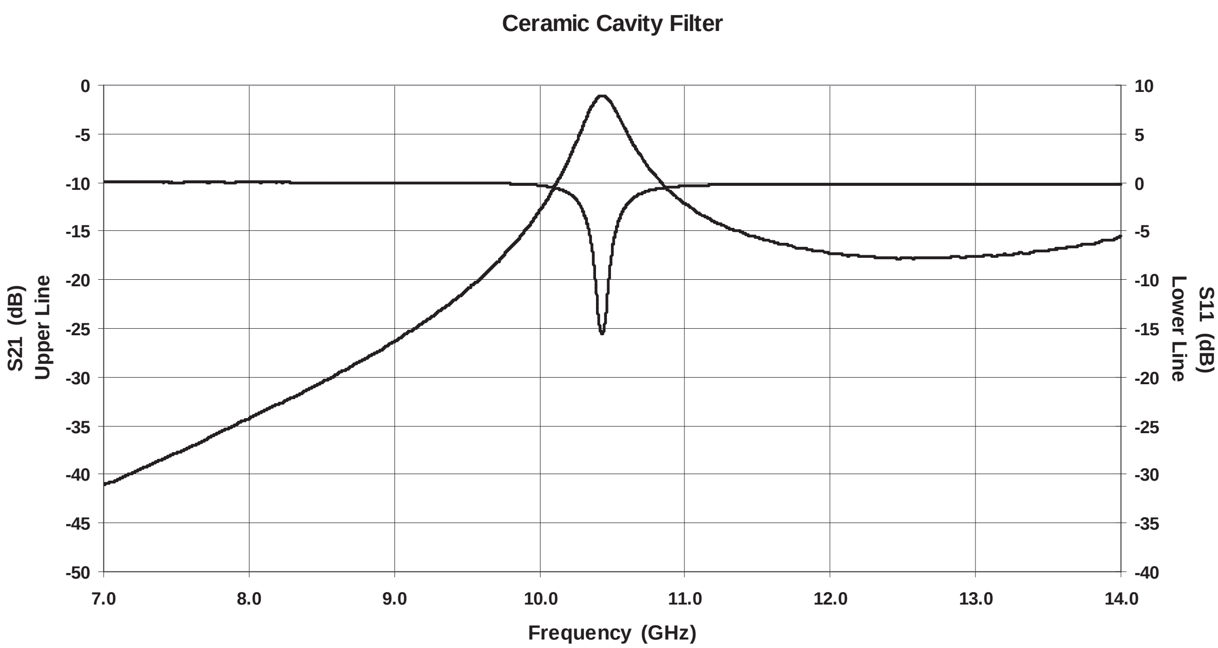
Patent Pending

Ceramic Cavity Filters

- Utilizes single pole ceramic cavity resonator design
- Small Size - 0.17 X 0.2 X 0.03 inches for a 10.5 GHz filter
- LO/Multiplier chains/RF pre-select/image filtering
- Patent Pending



10.5 GHz Ceramic Cavity Filter



Ceramic cavity resonator technology can be employed in conjunction with DLI's stable, high Q ceramics to create precise, small, low loss bandpass filters. Using a two port implementation, a very small robust filter can be created. Wide reject band performance without spurious modes is possible. The small, shielded nature of the ceramic cavity filter implementation makes it an ideal choice for integration in low noise receiver front ends with the antenna and pre-amplifier.

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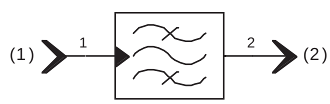
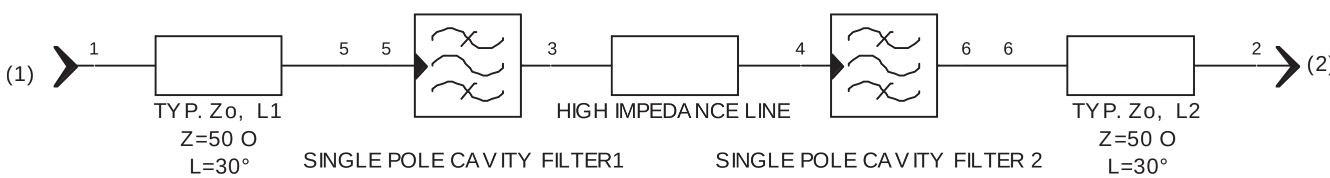
Cascading of Filters

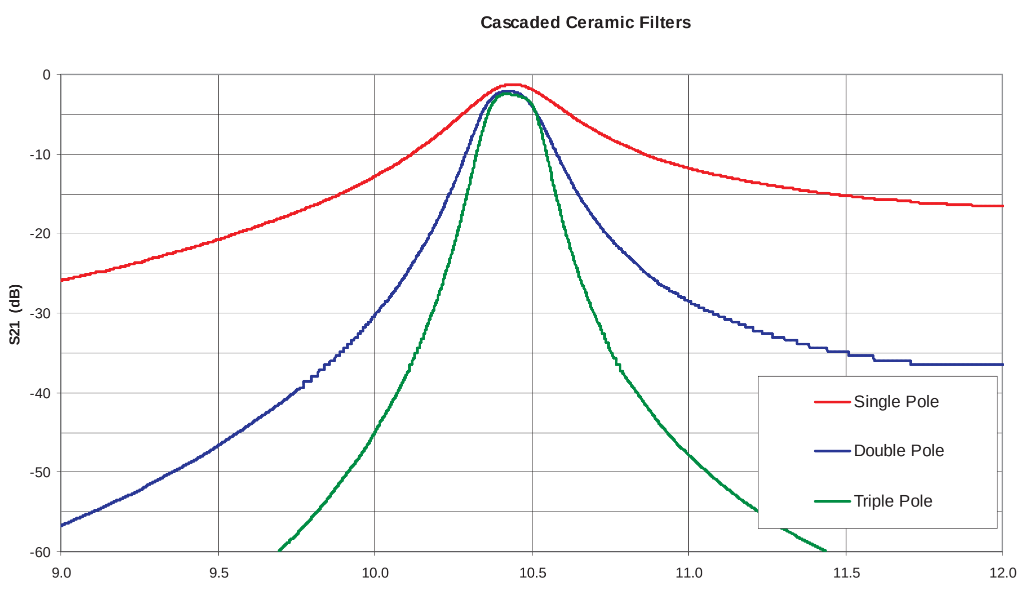
The filtering characteristics of a series-cascading ceramic cavity resonator is demonstrated below. The single ceramic cavity resonator which contains one resonator and generates one transmission zero is introduced as the most basic building block for modular design of Bandpass filters. Higher-order Bandpass filters are designed by cascading single cavity resonators to generate the required transmission zeros. A simple example model filter is designed to validate the model and the design approach. The performance of the cavity resonator filter, especially the bandwidth ratio, is improved significantly in comparison with that of the single cavity resonator filter. The synthesis and design of these filters are based on models which cascade the designed cavity resonator at the vicinity of center bandwidth frequency. In early designs, up to 3% relative bandwidths have been achieved.



SINGLE POLE CAVITY FILTER



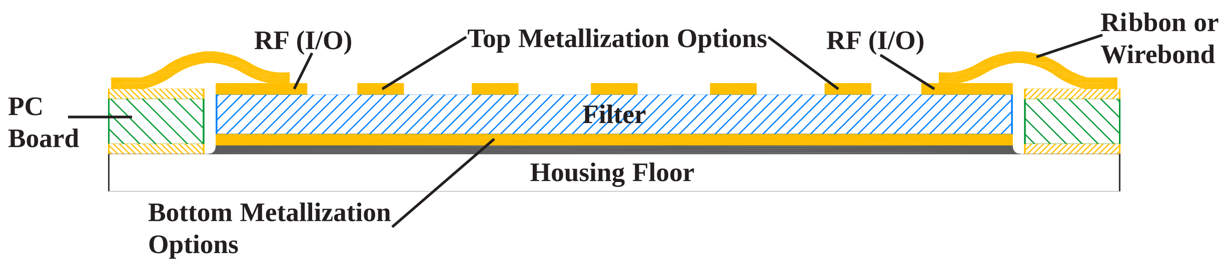
Two Single-Cavity Filters Cascaded at 10.4 GHz



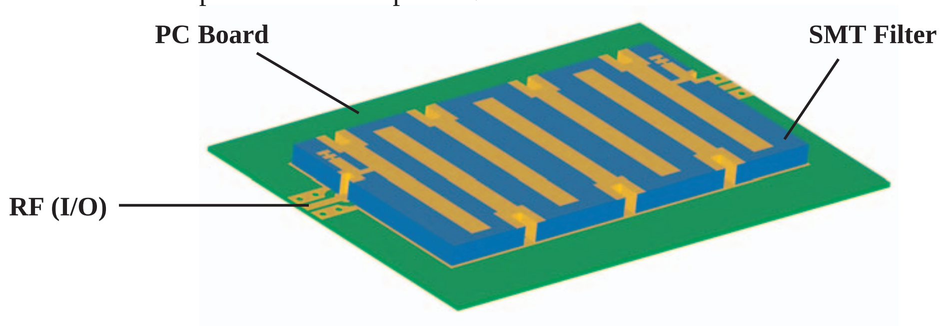
Cascaded Cavity Filter Performance

Mounting

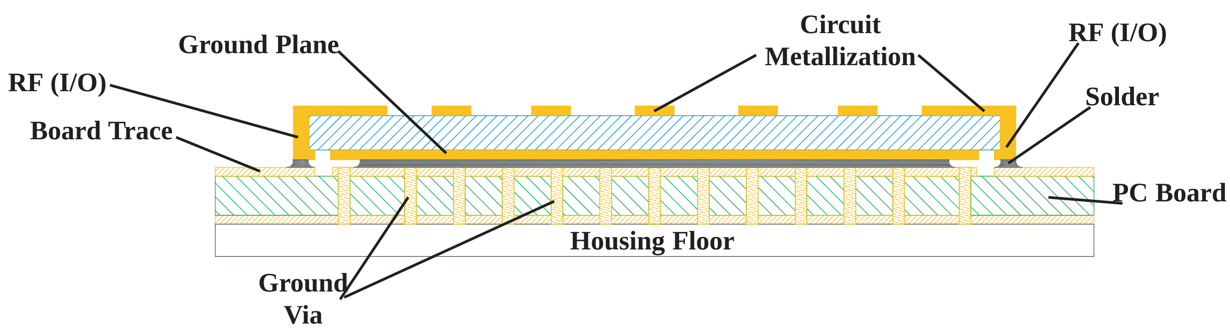
Two mounting techniques in common usage are designed to optimize performance of filters at microwave frequencies. Reliable connectivity is assured by selecting the correct metallization for the signal traces and mounting surfaces for the desired mounting and interconnecting technique. The metallization schemes offered support these mounting techniques. Customized metallization systems are available upon request.



The above illustration demonstrates a microstrip mounting technique. The circuit is relieved to accommodate the filter. The bottom surface of the filter is attached directly to the system ground plane using conductive epoxy. A minimum of 50 micro-inches and typically 100 micro-inches of gold are provided on the top surface to facilitate reliable wirebonding. [Cleaning of the surfaces using UV ozone etch or ultra-sonic techniques is always recommended to insure the highest quality of bonds.] Metallization codes W or M are suitable for this assembly method. If metallization code M is selected, solder attach of the part is enabled if thermal coefficients of expansion are compatible.



Surface mounting techniques typically rely on solder bond between the bottom conductor of the component and the ground conductor of the circuit. Note the use of multiple ground vias between the component and the system ground plane to insure optimal performance. The input/output signal connection can be realized using castellations and solder reflow. Nickel metallization is provided for solder attachment. A thin outer layer of gold is provided to prevent oxidation of the nickel. The gold is minimized to eliminate embrittlement in the solder joint. This metallization code is S.



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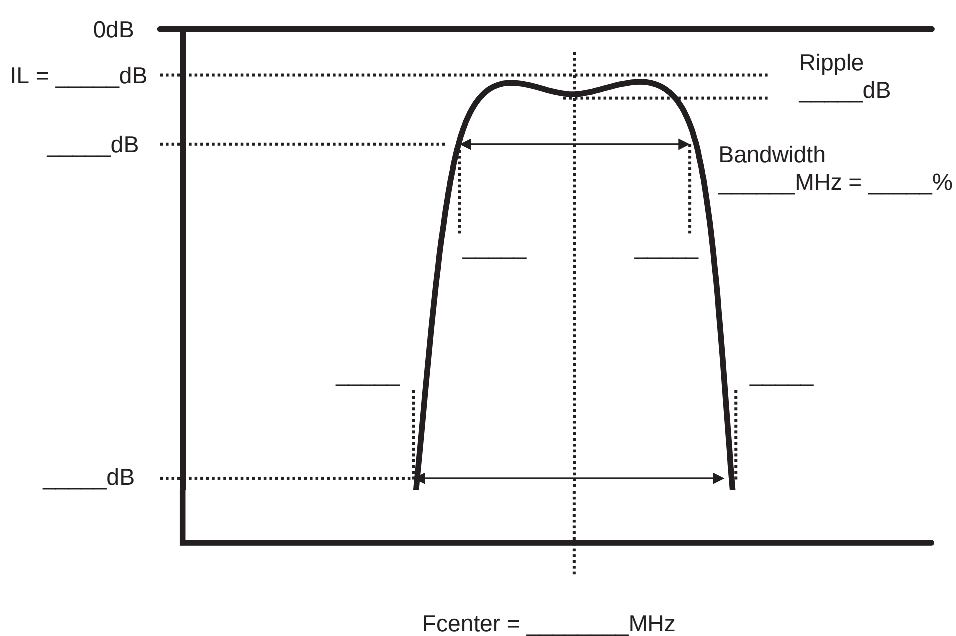
Custom Filters™

Defining a Custom Filter

Type –Bandpass (BP), Lowpass (LP), Highpass (HP)	
Center Frequency, Fc (GHz)	Fc=__________ GHz
3 dB Bandwidth (MHz)	BW3dB=_________ MHz
Insertion Loss (IL) @ Fc (dB)	IL=________ (dB)
Return Loss (RL) @ Fc: dB Reference - 50 Ohms	RL=_______ (dB)
Upper Frequency Rejection:	- _____ dB @ ______ MHz
Lower Frequency Rejection:	- _____ dB @ ______ MHz
Power Handling (Watts)	Power (average) =__________ Watts Power (peak) = __________ Watts
Operating Temperature Range:	T min =_______°C, T max =_______°C
Mounting Technique: Surface Mount (S) or Microstrip (M)	Circle one: **S** or **M**
Size (limits):	Length_____, Width______, Thickness_____, circle one: **inches** or **mm**



XTREME-Q

Ceramic Duplexers and Diplexers™

DLI utilizes the unique advantages offered by its proprietary ceramic formulations as the differentiator from typical RF and Microwave manufacturers. DLI will design both Duplexers and Diplexers to customer specifications. The distinction between the two is subtle, but the understanding is essential to proper design. **Duplexers** are three port devices used to separate and combine frequencies, having two filters with a common driving point covering two frequency bands. **Diplexers** are three port devices used to separate and combine frequencies, having one filter covering all frequency bands

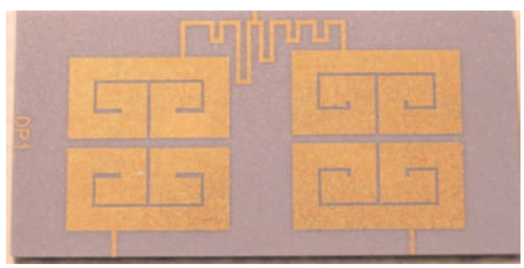
Typical Specifications

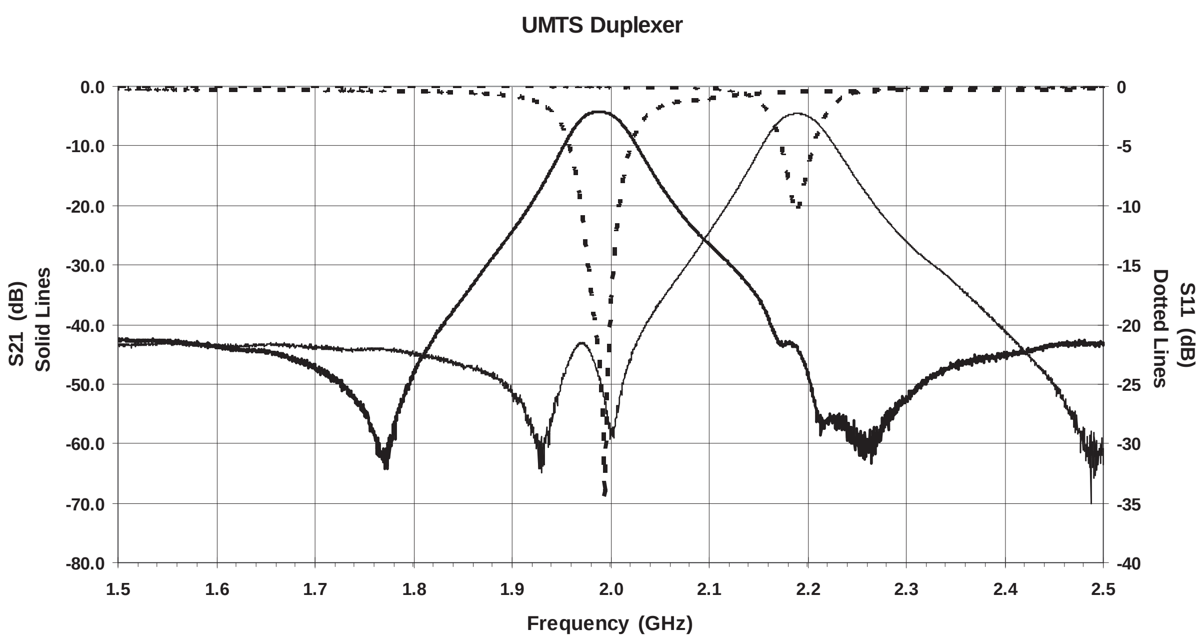
- Frequencies from 1 to > 67 GHz
- Insertion loss < 3 dB
- Return loss 20 dB minimum
- Isolation > 50 dB

Features and Benefits

- Highly integrated SMT or wirebond formats
- Available in gold and copper metallizations
- Photolithography defined
- Accurately reproducible

Below is one example of a UMTS Duplexer. This discrete ceramic Duplexer utilizes high performance ceramic thin film materials from DLI. Thin film technology offers these types of devices with the ability to meet conflicting and challenging demands for size reduction, low insertion loss, bandwidth, as well as ideal matching conditions. In this case the DLI designed device eliminated 2 separate filters and an isolator in one-fifteenth the size of a PWB implementation with far better temperature stability.





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Bias Filter Network

Designed to filter RF signals from bias and control lines from 10MHz to 40GHz

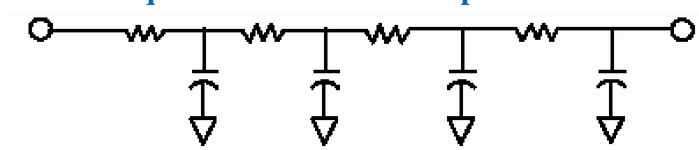
Functional Applications

- Wireless communication modules
- Ideal varactor decoupling element
- High gain RF/Microwave modules
- Ideal GaAs FET gate biasing device
- MMIC multichip modules

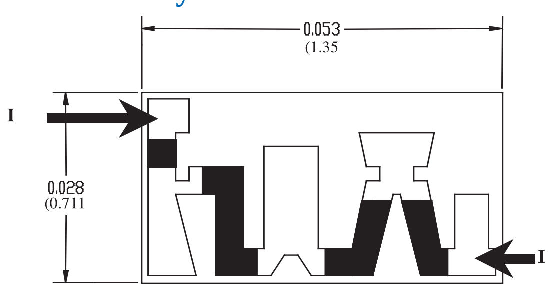
Benefits

- Filters noise and RF from Supplies.
- Reduces RF feedback through bias supplies.
- Simplifies assembly - one component replaces many.
- Designed with large 4 mil wirebond pads for assembly ease.

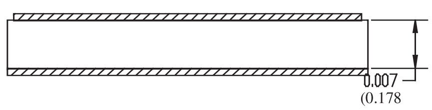
Equivalent Schematic Representation



Physical Characteristics



Dimensions in inches (mm)
L / W & T tolerance ± .001" (.0254)



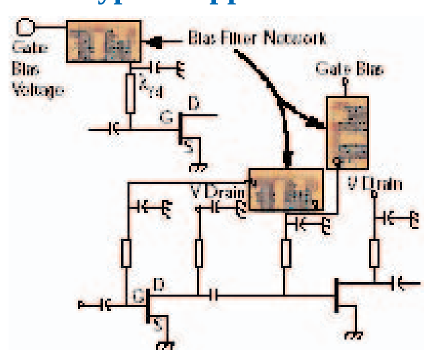
Total Series Resistance:
600 nominal

Total Shunt Capacitance:
BT material - 140pF nominal
BH material - 95pF nominal

DC Ratings: Volts Max:50V I(mA) Max:10Ma

Recommended Mounting: The Bias filter Network should be mounted with fully metallized side down directly on RF ground plane for maximum isolation performance.

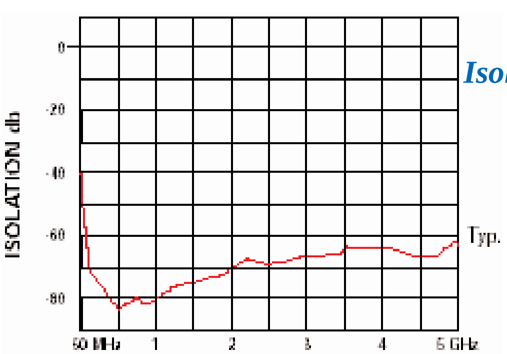
Typical Applications

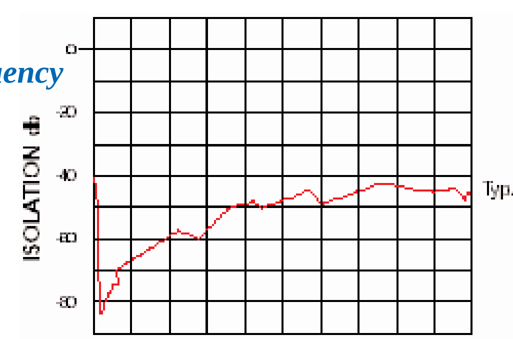


Part Number Identification

B	28	BH	BFN01
Product B = Bias Network	**Width** 28	**Material** BH ± 15% TC BT +22,-56% TC	**Network Type**

Isolation vs Frequency





Custom Filters can be designed per customer specification. Please consult factory for additional information or special requirements

DIELECTRIC LABORATORIES
A DOVER COMPANY

Gain Equalizer

Used to compensate for the Gain Slope of other elements

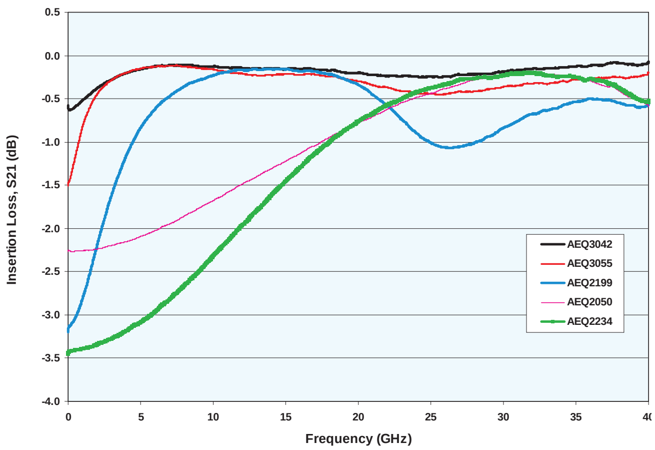
Functional Applications

- Equalizer compensates for module Gain Slope
- Broadband communications, RADAR, phased arrays
- SONET modules to 40+ GHz

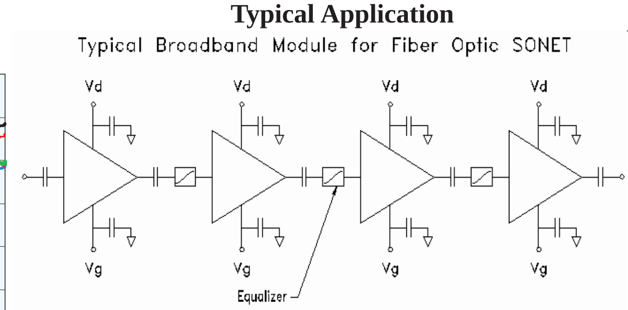
Benefits

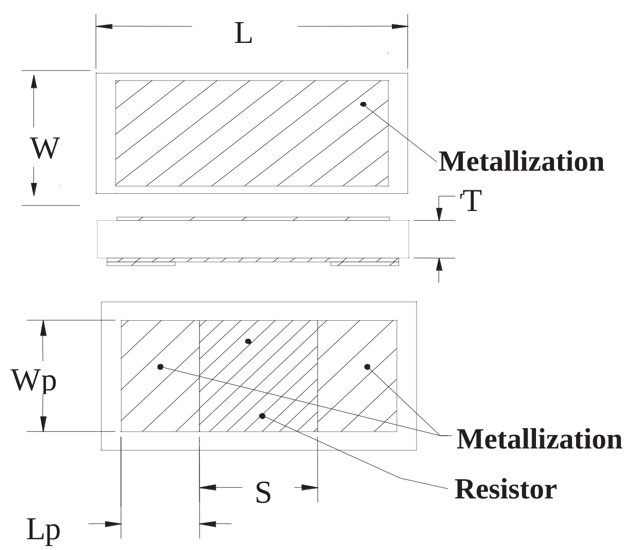
- Superior microwave performance
- Excellent repeatability
- Ease of assembly, reduced size and cost

Performance



Typical Application





Excellent, repeatable microwave performance is achieved by application of precision thin film fabrication and DLI Hi-K Ceramic materials. DLI's unique design solution provides near Ideal R-C frequency response, far superior to "Stacked R-C chip" Assemblies.

Part #	Resistor (R)	Low Frequency Insertion Loss, 50 ohm system (dB)	Equivalent Capacitance (pF)	F_o (GHz)	Mounting Attachment material: S=solder E=epoxy	L	W	T
AEQ 2199	43 Ω	-3.0	1.15	16	E	0.028” ± .002” (.711 ± .051 mm)	0.016” ± .002” (.406 ± .051 mm)	0.007” ± .001” (.178 ± .025 mm)
AEQ 2050	30 Ω	-2.2	0.33	34	E	0.030” ± .002” (.762 ± .051 mm)	0.016” ± .002” (.406 ± .051 mm)	0.005” ± .001” (.127 ± .025 mm)
AEQ 2234	50 Ω	-3.5	0.31	32	E	0.032” ± .002” (.813 ± .051 mm)	0.018” ± .002” (.457 ± .051 mm)	0.005” ± .001” (.127 ± .025 mm)
AEQ 3042	9 Ω	-0.8	12.5	7	S	0.040 ± .002” (1.02 ± .051 mm)	0.020 ± .002” (.508 ± .051 mm)	0.006 ± .001” (.152 ± .025 mm)
AEQ 3055	20 Ω	-1.6	9.0	7	S	0.040 ± .002” (1.02 ± .051 mm)	0.020 ± .002” (.508 ± .051 mm)	0.006 ± .001” (.152 ± .025 mm)

Custom Equalizers can be designed per customer specification. Please consult Factory for additional information

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Gain Equalizer

Metallization:

Epoxy mount (type "E"): Top side: TaN resistor, TiW, 100 μ inch Au minimum.
Bottom side: TiW, 100 μ inch Au minimum.
Solder mount (type "S"): Top side: TaN resistor, finish: 20 μ inch Au maximum over 30 μ inch Ni
Bottom side finish: 20 μ inch Au maximum over 20 μ inch Ni

Die Attachment recommendations:

The gap in the microstrip line should nominally be equal to dimension "S" (see table).

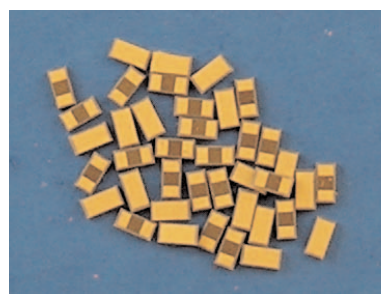
Mounting attachment material:

"E" type are conductive epoxy only
"S" type can be solder or conductive epoxy

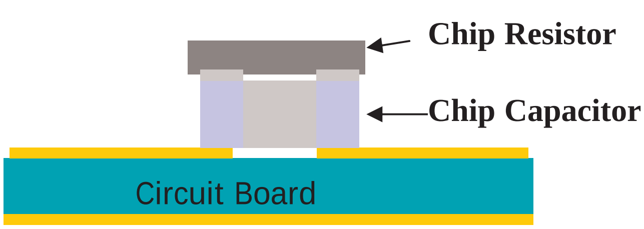
Part Number Identification

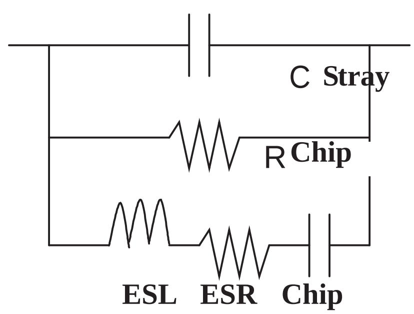
AEQ	34	R50	S	T	-XXXX
Product Family	Minimum Loss Frequency	Resistance in ohms	Mounting Technique	Package	Drawing #
	GG in GHz	R50=50 ohms	S=solder attach	T=tape/reel	
	Ex: 34 is 34GHz		E=epoxy mount	P=waffle pack	

DLI's miniature Thin Film Gain Equalizers have a microwave frequency response which is so close to ideal that it can be modeled by the simple parallel R-C circuit shown on the preceding page. This is a convenient model for Spice (time domain) simulations. Other common equalizer implementations using stacked R-C chips are not accurately modeled by this circuit. For highest accuracy frequency domain simulations, S-parameters are recommended



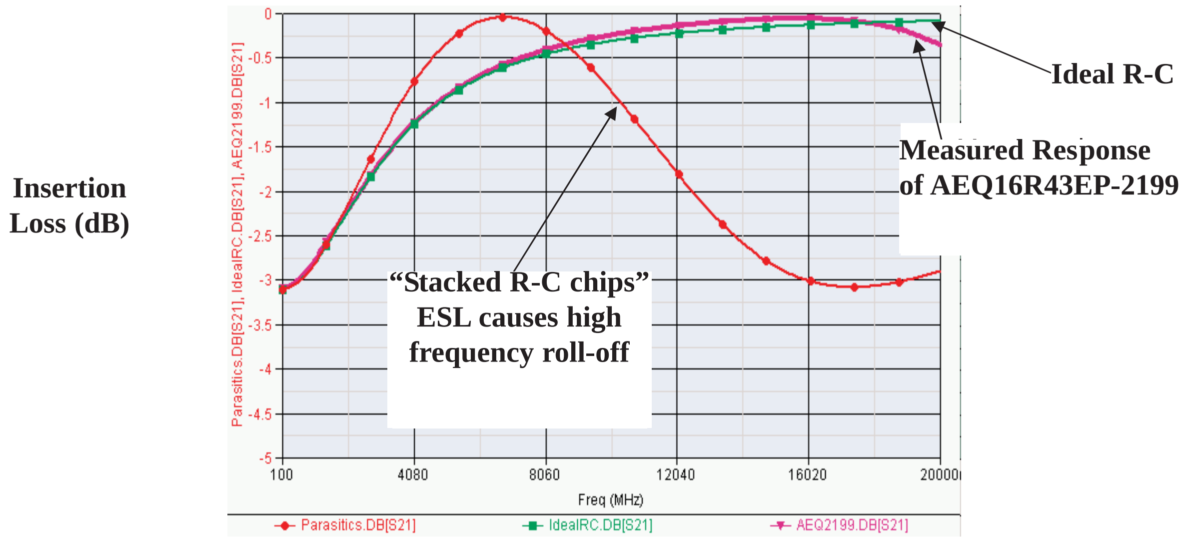
The "stacked R-C chip" implementation, illustrated in the figure below has many issues in both design and manufacturing which lead to lower performance, and higher product cost. The equivalent circuit model below more accurately predicts the frequency response of the stacked chips. At microwave frequencies, the additional parasitic circuit elements are required. The effect of ESL, the equivalent inductance of the chip capacitor is particularly important as it causes a more peaked response as seen in the figure on the next page.





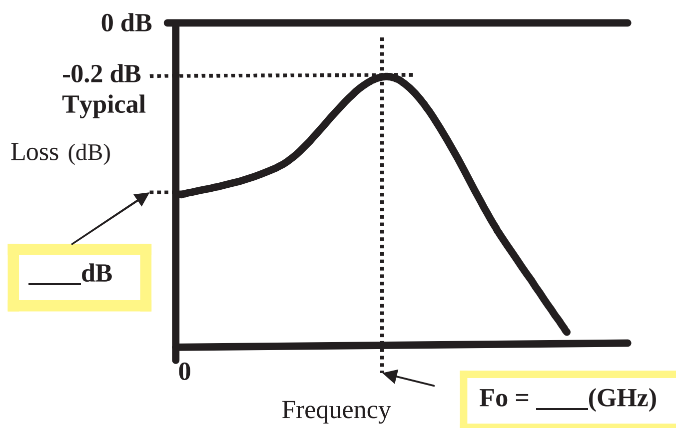
Gain Equalizer

DLI's gain equalizer frequency response is compared with that of an ideal R-C, and stacked R-C chips in the figure below. The stacked R-C chip model utilizes the same Rchip and Cchip values as in the ideal R-C model. The key point is that the chip component R and C values used in a stacked chip equalizer are generally not the ideal values for specifying the DLI single chip gain equalizer. The next section discusses specifying the part by frequency response parameters, or in terms of the ideal R-C values.



Custom Equalizer Design Inputs:

- Low frequency loss or resistance value
- Fo minimum loss frequency or capacitance determined using equivalent circuit model on page 32.
- Case size restrictions - 50 ohm microstrip line width is a typical maximum case width objective



Case Size (inches)	Preferred:_____________ Maximum Length:________ Maximum Width:________
Minimum Loss Frequency (GHz)	Fo________ GHz
Low Frequency Loss (**dB**), 50 ohm system	Design Resistance (ohms)________ Loss(dB)________
Operating Temperature Range (C°)	Minimum Temperature: ________ Maximum Temperature:_______
Power Dissipation (mw)	
Assembly Method (SMT or Epoxy)	Conductive Epoxy attach______ Solder attach______ Solder type____________
Board Material	Material ________ Dielectric constant _______ Thickness_________

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Di-Cap®
Highest performance SLC for RF, MW and MMW applications from 100 MHz to 100 GHz .
Most cap for size
0.02 - 4300 pF

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SLC w/1- or 2-sided recessed metallization to minimize the potential for shorting during die attach.
Ideal for epoxy attach.
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Gap Cap
Series configured precision SLC for elimination of wire-bonds and microstrip applications.
Minimum performance variation.

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Multiple decoupling/ bypass or blocking SLC configured in a single array.
Ideal for decoupling MMICs.

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Multi-value - binary tunable SLC for design tuning or MIC hybrids.

T-Cap
SLC used in series connected open circuited transmission line and is designed for repeatable resonance behavior.

Multi-Layer Capacitors

C04	C06	C08	C11	C17	C22	C40
0.04 x 0.02	0.06 x 0.03	0.08 x 0.05	0.055 x 0.055	0.11 x 0.11	0.22 x 0.25	0.38 x 0.38
0.1 – 10pF	0.1 – 47pF	0.1 – 100pF	0.1 - 100pF	0.1 – 1000pF	1 - 2700pF	1 - 5100pF
UL only	UL & CF	UL only	UL, CF, AH	UL, CF, AH	CF & AH	CF & AH
100V WVDC	250V WVDC	250V WVDC	250V WVDC	1000V WVDC	2500V WVDC	7200V WVDC

Build-to-Print Thin Film Processing

Let DLI be your complete Thin Film Foundry. DLI has provided comprehensive build-to-print services to its customers for years. You can leverage decades of ceramic and thin film processing experience, prototyping and testing capabilities, and engineering support to meet your exacting needs.

Precision Variable Capacitors

Voltronics Corporation is one of the world's largest and most respected precision variable capacitor manufacturers. Consistent product quality, excellent customer service and product customization flexibility set Voltronics apart from its competitors. Whether it's a reliable high voltage or a high purity non-magnetic or a lower cost high performance application, Voltronics has the right variable capacitor for you. Voltronics has been a Dover company since 2004.

Teflon
Low cost, miniature
0.3 thru 12 pF
Available in non-mag
Surface mount

High Voltage
Up to 2KV
0.2 thru 55 pF
Extended Voltage
Up to 15KV
0.1 thru 85 pF
Available in non-mag

Glass & Sapphire
Sealed sapphire
0.6 thru 8 pF
Available in non-mag
Surface mount

Sealed Glass
1.0 thru 250 pF
Surface mount
Vertical, panel & Horizontal Mount

Air
Solder sealed
0.6 thru 14 pF
Surface mount

Epoxy sealed
0.6 thru 14 pF
Surface mount

Ceramic
Low cost 1/2-turn
1.25 thru 130 pF
Surface or through-hole mount

Higher voltage single turn
Surface or through-hole mount

Non-caps
Custom inductors, diodes and screws
Non-magnetic only

Connectors & Cable Assemblies PC Plug, Straight & 90º Crimp Jack
Non-magnetic only

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微波光电部专业研制、代理经销高频、微波、光纤、光电元器件、组件、部件、模块、整机；电磁兼容元器件、材料、设备；微波CAD、EDA 软件、开发测试仿真工具；微波、光纤仪器仪表。欢迎国外高科技微波、光纤厂商将优秀产品介绍到中国、共同开拓市场。长期大量现货专业批发高频、微波、卫星、光纤、电视、CATV 器件: 晶振、VCO、连接器、PIN 开关、变容二极管、开关二极管、低噪晶体管、功率电阻及电容、放大器、功率管、MMIC、混频器、耦合器、功分器、振荡器、合成器、衰减器、滤波器、隔离器、环行器、移相器、调制解调器；光电子元器件和组件：红外发射管、红外接收管、光电开关、光敏管、发光二极管和发光二极管组件、半导体激光二极管和激光器组件、光电探测器和光接收组件、光发射接收模块、光纤激光器和光放大器、光调制器、光开关、DWDM 用光发射和接收器件、用户接入系统光光收发器件与模块、光纤连接器、光纤跳线/尾纤、光衰减器、光纤适 配器、光隔离器、光耦合器、光环行器、光复用器/转换器；无线收发芯片和模组、蓝牙芯片和模组。

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