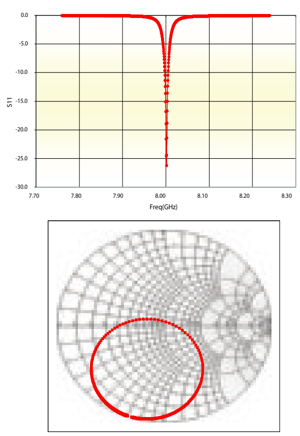
Resonators

DLI has a family of patent pending high-Q ceramic cavity resonators. They provide an ideal solution for high performance, low-cost microwave, or millimeter wave oscillators. The devices are fully shielded and designed on our temperature stable, high dielectric constant ceramics.

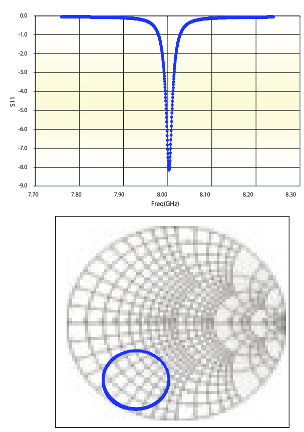
DLI has developed an equivalent circuit modeling tool for cavity resonators. The tool enables optimization of resonator based oscillator designs and constrains circuit element values to realizable combinations. Below are example models at 8GHz. Two models are shown using CF ceramic, one using FS, and one using CG.

Please consult DLI Applications Engineering for a copy of the modeling tool.

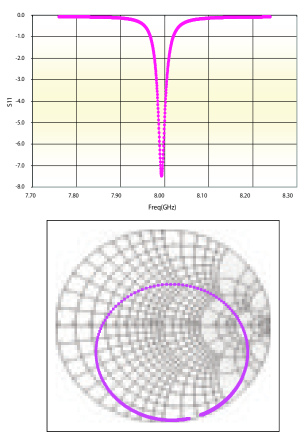
CF (design 1)



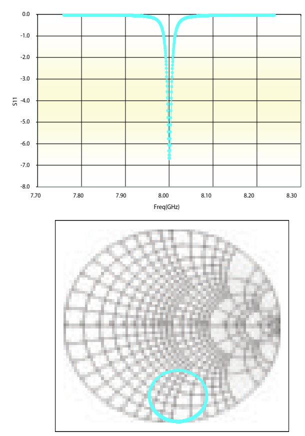
CG



FS

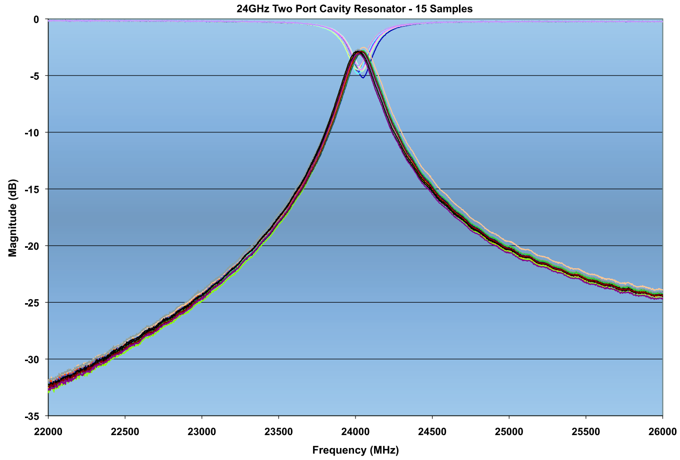


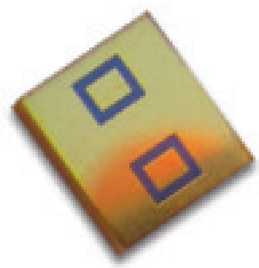
CF (design 2)



Two port resonators can also be realized for varactor-tuned oscillator and feedback oscillator applications. The devices can also be implemented as one-pole bandpass filters. These are fully shielded and designed on temperature stable ceramics like the one port resonators. Below is required information for a two port resonator design and measured test data of a two port resonator at 24GHz.

Electrical Specification		General Information	
Resonant Frequency	Fc =______GHz Tolerance:___%	Resonator Application	Varactor - Tuned OSC Feedback OSC Filter
Doubly Loaded Q	QL =______	Size Restriction	Max width:______ Max length:______ Max thickness:_____
Maximum Insertion Loss At Fc	IL =_______dB	Assembly Type	Solder Surface Mount Epoxy Attach

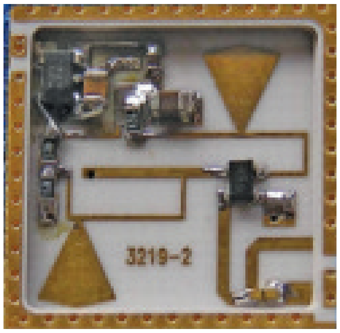




Resonators

Frequencies of resonator designs range from <1.0 to >67GHz. Designs can be customized for either solder-surface mount or chip and wire applications. High reliability thin film gold metallization is employed and frequency tolerances as low as 0.1% are attainable.

The chart below depicts possible resonator applications.



6.8GHz oscillator using DLI ceramic resonator technology

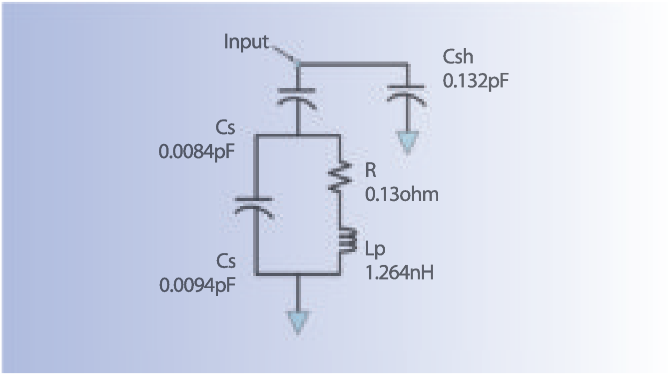
A Sample of Applications

Systems	**Circuits**
Automotive	**Microwave & Millimeter-Wave Oscillators**
RADAR Ground-based Avionics/Missile Shipboard	**Fundamental Fixed Frequency Oscillators - Ultra-low Phase Noise** (*former solution:* expensive DRO's and multiplied-up crystal or SAW based device with decreased performance)
Communications Base Stations WLAN, WLL SONET/SDH	**Narrow-Band Tunable VCO or Phase Locked Oscillators** (typically ± 3% tuning) (*former solution:* varactor tuned expensive DRO)
Military RFID ECM/ECCM/EW Tx/Rx Man Pack Radio Aerospace Intelligent Munitions	**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)
Instrumentation	

**Note that DLI resonators are direct in frequency. So in addition to all of the other benefits no multiplication is required as there would be in other technologies. As a solid block of ceramic they are also non-microphonic.......Imagine the possibilities!

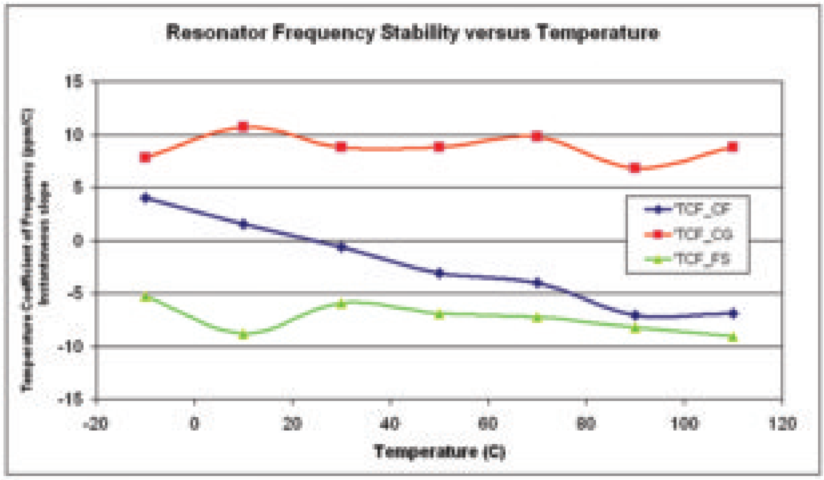
Single Frequency Cavity Resonator

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 above. 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.

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



Single Frequency Cavity Resonator

Representative Sampling of Resonator Characteristics

Resonant Frequency (GHz) *1	Material	Temperature Coefficient of Frequency *2 Typical 9PPM/°C)	Return Loss @ Resonance Typical (dB)	Loaded Q Typical (50 OHMS)	Dimensions L x W x T mm	Dimensions L x W x T Inches
3.2	CG	+8.8	-22	290	8.1 x 8.1 x 3.0	0.32 x 0.32 x 0.12
5.0	CF	-2.3	-12	550	8.1 x 8.1 x 3.0	0.36 x 0.36 x 0.12
5.0	CG	+8.8	-12	360	5.1 x 5.1 x 3.0	0.20 x 0.20 x 0.12
5.0	FS	-7.3	-12	1000	21.8 x 21.8 x 3.8	0.86 x 0.86 x 0.15
6.8	FS	-7.3	-9	1050	15.7 x 15.7 x 3.0	0.62 x 0.62 x 0.12
8.2	CF	-2.13	-25	250	5.3 x 5.3 x 0.8	0.21 x 0.21 x 0.03
9.95	CF	-2.3	-11	300	5.6 x 4.3 x 0.8	0.22 x 0.17 x 0.03
12.8	CF	-2.3	-7	350	3.8 x 3.6 x 0.8	0.15 x 0.14 x 0.03
18.65	FS	-7.3	-25	400	6.1 x 5.6 x 1.0	0.24 x 0.22 x 0.04
24.0	CF	-2.3	-12	480	21.8 x 21.8 x 3.8	0.86 x 0.86 x 0.15
24.0	FS	-7.3	-12	1000	4.6 x 4.6 x 3.0	0.18 x 0.18 x 0.12
26.5	FS	-7.3	-20	325	4.2 x 4.2 x 0.5	0.16 x 0.16 x 0.02
40	FS	-7.3	-18	445	2.7 x 2.7 x 0.5	0.10 x 0.10 x 0.02
50	FS	-7.3	-17	400	2.2 x 2.2 x 0.5	0.08 x 0.08 x 0.02
67	FS	-7.3	-12	600	1.6 x 1.6 x 1.0	0.06 x 0.06 x 0.04

*1 Frequency Tolerance 0.1~ 1%

*2 Over the range -60°C to + 125°C

The table above summarizes the characteristics of selected standard resonators to illustrate the primary resonator design variables. The primary variables are frequency of resonance, cavity material dielectric constant and length-by-width dimensions. The interaction of these variables is illustrated in the resonator size charts on page 19. The loaded Q of the resonators is effected by the coupling coefficient (denoted in the tables in terms of return loss), the 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 resonant frequency and the unloaded Q will be 2 times the loaded Q value. The desired level of resonator coupling varies with individual circuit requirements such as varactor frequency tuning or transistor negative resistance value. The unloaded Q's of the cases shown range up to 2,000, clearly a new standard for a component compatible with automated assembly. In contrast to other "high Q" microwave resonators, DLI's cavity resonator is completely self contained. Large, expensive housings are not needed. 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.

Single Frequency Cavity Resonator

Standard Frequencies for SFCR

DLI has established a series of standard specific frequency resonators (EAR 99) which have the ability to be laser trimmed down in frequency by approximately 2% of the actual resonant frequency. The resonators incorporate lithography defined 'snake eyes' that the laser can recognize as a starting point to trim through the gold. Frequencies above and below this range of standard frequencies are obtainable. Please contact DLI Applications Engineering for more details.

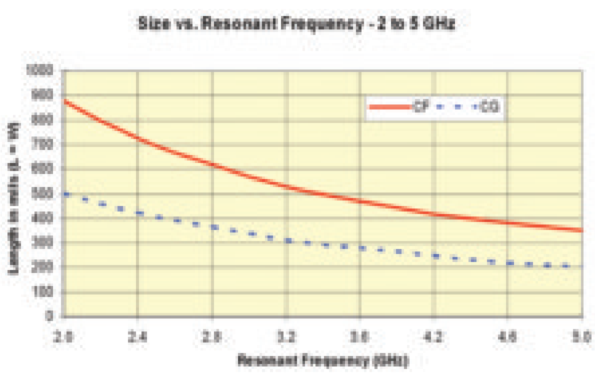
Resonant Frequency (MHz)	Tunable Range (MHz)	Resonant Frequency (MHz)	Tunable Range (MHz)	Resonant Frequency (MHz)	Tunable Range (MHz)
3000	60	11600	232	28000	560
3100	62	11800	236	28500	570
3200	64	12000	240	29000	580
3300	66	12200	244	29500	590
3400	68	12400	248	30000	600
3500	70	12600	252	30600	612
3600	72	12800	256	31200	624
3700	74	13000	260	31800	636
3800	76	13200	264	32400	648
3900	78	13400	268	33000	660
4000	80	13600	272	33600	672
4100	82	13800	276	34200	684
4200	84	14000	280	34800	696
4300	86	14200	284	35000	700
4400	88	14400	288	35700	714
4500	90	14600	292	36400	728
4600	92	14800	296	37100	742
4700	94	15000	300	37800	756
4800	96	15300	306	38500	770
4900	98	15600	312	39200	784
5000	100	15900	318	39900	798
5200	104	16200	324	40000	800
5400	108	16500	330	40800	816
5600	112	16800	336	41600	832
5800	116	17100	342	42400	848
6000	120	17400	348	43200	864
6200	124	17700	354	44000	880
6400	128	18000	360	44800	896
6600	132	18300	366	45000	900
6800	136	18600	372	45900	918
7000	140	18900	378	46800	936
7200	144	19200	384	47700	954
7400	148	19500	390	48600	972
7600	152	19800	396	49500	990
7800	156	20000	400	50000	1000
8000	160	20400	408	51000	1020
8200	164	20800	416	52000	1040
8400	168	21200	424	53000	1060
8600	172	21600	432	54000	1080
8800	176	22000	440	55000	1100
9000	180	22400	448	56100	1122
9200	184	22800	456	57200	1144
9400	188	23200	464	58300	1166
9600	192	23600	472	59400	1188
9800	196	24000	480	60000	1200
10000	200	24400	488	61200	1224
10200	204	24800	496	62400	1248
10400	208	25000	500	63600	1272
10600	212	25500	510	64800	1296
10800	216	26000	520	66000	1320
11000	220	26500	530	67000	1340
11200	224	27000	540		
11400	228	27500	550		

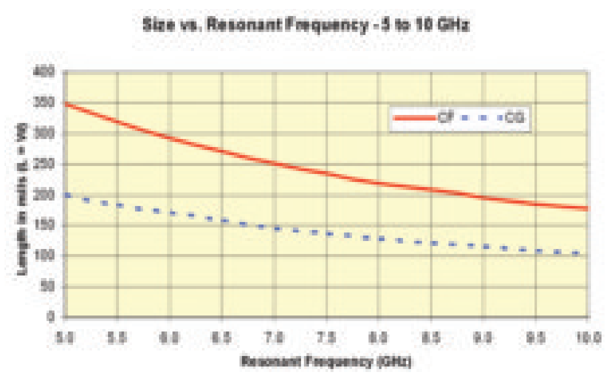
Single Frequency Cavity Resonator

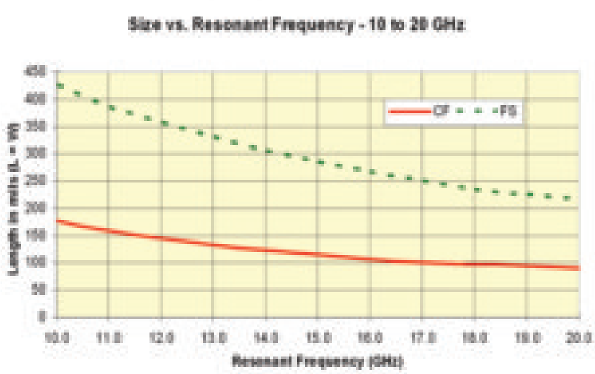
Estimating Resonator Size

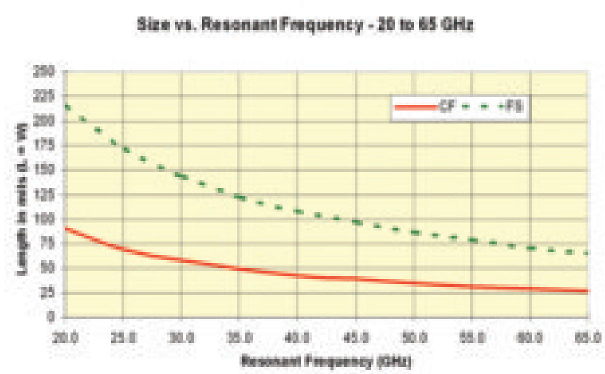
The size of the cavity resonator is determined by the desired resonant frequency and the ceramic material selected. At the same resonant frequency, a higher dielectric constant material will offer reduced size compared to a lower dielectric constant material. Resonators are typically designed on thick ceramics due to Q increasing with material thickness.

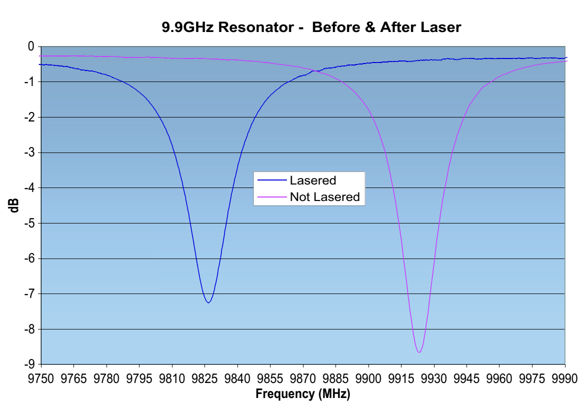
The charts on this page can be used as a guide for estimating resonator sizes on typical DLI materials. Designs are slightly rectangular in shape. Length to width aspect ratios are usually less than 1.2:1. For additional information consult the factory.









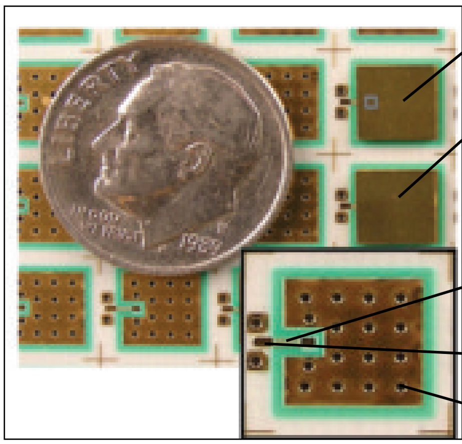


The graph to the left shows a 9.9GHz resonator tuned down in frequency by laser trimming slots through the gold metallization. In this particular example the part was lasered approximately 96MHz lower than its true resonant frequency.

Tuning resonators up in frequency is possible by using photolithography to define slots on the top side of the resonator circuit. Wirebonding across the slots will tune the device up in frequency.

Single Frequency Cavity Resonator

Mounting Alternatives

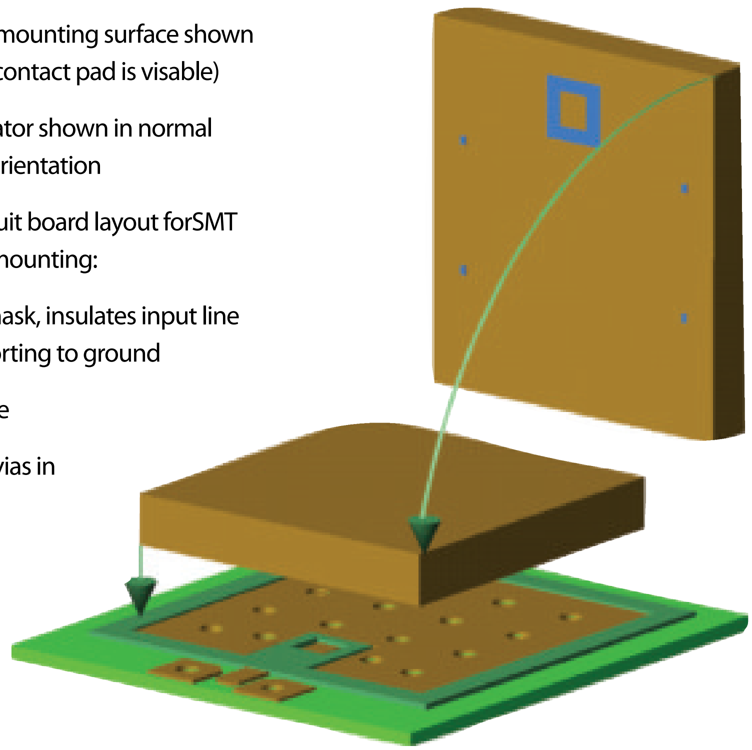


1) Resonator mounting surface shown facing up (contact pad is visable)

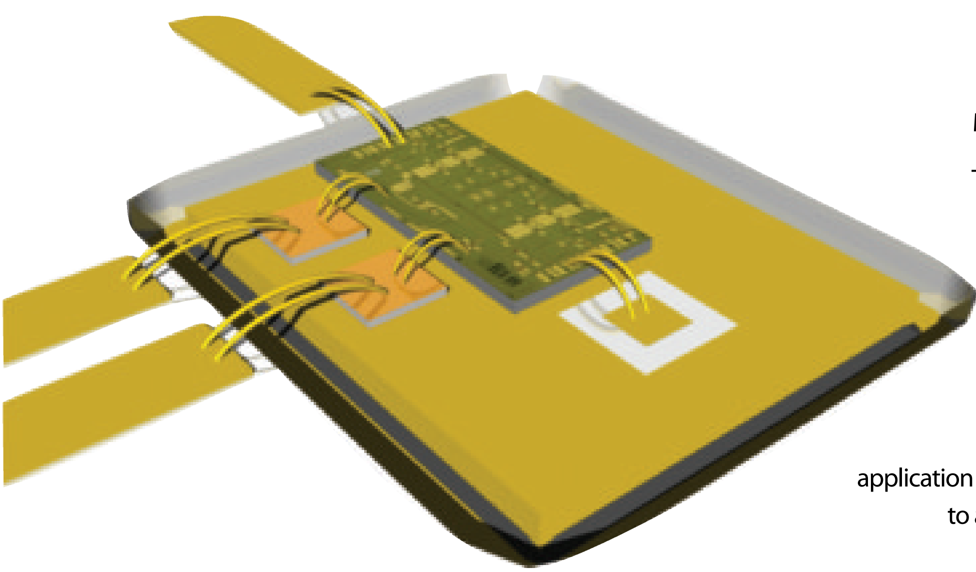
2) SMT resonator shown in normal mounted orientation

3) Typical circuit board layout forSMT resonator mounting:

- **a)** Solder mask, insulates input line from shorting to ground
- **b)** Input line
- **c)** Ground vias in board



The illustrations above demonstrate 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 [1]. The second illustration shows the resonator mounted in position [2]. The third illustration shows the printed wire board geometry [3a-c]. 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. A solderable metal scheme with a nickel barrier will be employed on the resonators. A thin outer layer of gold will prevent oxidation of the nickel.



Microstrip Mount

This picture illustrates a microstrip mounting technique. Shown is an implementation where the active device and power supply bypass capacitors are assembled onto the resonator. The wirebond signal leads are kept as short as possible. In a typical application conductive epoxy would be used to attach the resonator to the circuit.