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Optimization and Design of Inverted Ring Resonator for Q and centre frequency using IE3D AND HFSS

Nishant Mittal Rutika Lahoti Savita Kulkarni Dr. Madhuri Joshi

***Abstract*— An attempt to design and develop optimized inverted microstrip resonator with Q greater than 200 is presented in this paper .The resonators with high Q was developed and design parameter was simulated using electromagnetic simulation software IE3d and HFSS. The resonator so designed was compared with the grounded ring resonator for the parameters like Q, Centre frequency and losses. Optimization of inverted ring resonator with respect to Q and frequency by varying various physical parameters for the resonator was done. Matlab-7 is used successfully to optimize the design parameter with respect to physical dimensions of structure. Preliminary development shows the results within 2% error.**

Index Terms—**Centre frequency, coupling gap, Finite element method, HFSS, IE3d, Inverted ring resonator ,Q, RT-Duroid 5880**

I. INTRODUCTION

Microstrip resonators are frequently employed in microwave integrated circuit design .Different resonant structures have been developed by scientists and researchers which include straight, ring, rectangular, circular resonators etc.[3]Resonators are widely used for microwave circuits in filters, couplers and application wise they are used in mobile circuits , permittivity measurement etc .It is a known fact that with the optimization of Q i.e by making the slope for Q steeper and straight we get very high sensitivity for the resonant frequency to occur. The same principle has been deviced in order to increase the Q of the microstrip ring resonator using various techniques. The mathematical design of the inverted and suspended ring resonators was done for the frequency of 2.45Ghz .[1],[4]

The mathematical modeling of the resonator is done using the Finite element method. The equations so derived for the dimensions of the resonator are obtained after a number of iterations using the Finite element method.[1] Once the dimensions match the required criteria the dimensions are plotted in the electromagnetic simulation software in order to obtain the S11 and S21 parameters to check if the required criteria is met.

In the stripline, all the fields are contained within a homogeneous dielectric region; microstrip has some of its field line in the dielectric region, concentrated between the strip conductor and the ground planes, and some fraction in the air region above the substrate. Thus microstrip line cannot support a pure TEM wave, since phase velocity is $c/\sqrt{\varepsilon_r}$ in the dielectric substrate, but phase velocity of TEM fields in air region is c [5]. The mode is called as Quasi-TEM mode of propagation. In practical applications, however, dielectric substrate is electrically very thin (d << lambda), so the fields are quasi TEM. Thus a good approximation for the phase velocity, propagations constant, characteristic impedance can be obtained from quasi-static solutions.[4],[5],[6].

It has been observed from previous papers and journals that it is practically very difficult to mechanically construct inverted resonators because of its design constraints. Also no paper directly talks about the design of an inverted microstrip ring resonator. An appropriate attempt has been made on this grounds in order to obtain the mathematical equations and optimized inverted ring resonator.

II. DESIGN OF INVERTED RESONATOR

A simple microstrip line is a continuous line in which there is transmission of signal from one side with mere reflections. But resonators come under different case .A resonator is not continuous. There is a coupling gap between the 2 feeding points which is responsible for trapping the field in the ring so that the signal continuously reflects back and forth in order to obtain resonance at a particular frequency as designed. This coupling gap should be designed such that it critically couples the signal coming from the transmitter end [4] [6]. A ring type of structure has been proposed here in order to reduce the open line problems in straight resonators causing losses. [6]

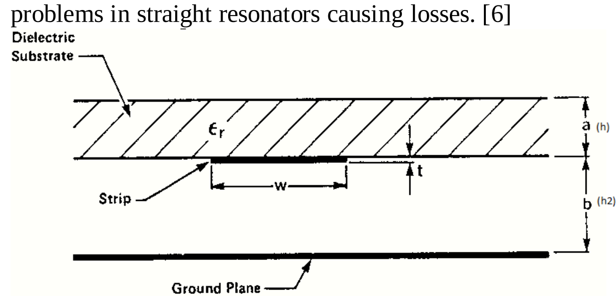

Fig 1 Inverted Microstrip structure

The basic features which are needed in order to design the microstrip ring resonator are

a) Line width *w*, Line thickness *t* ,Line losses α Substrate thickness *h*, Substrate dielectric constant ε.

b) Substrate losses: loss tangent *tan*(δ) Radiation losses

c) Main parameters: Characteristic impedance *Z* Effective dielectric Constant *εeff* [2]

The system has to be properly matched in order to obtain less losses. 50 ohm standard termination is taken into consideration for design. In order to design the system the following equations have been designed.[1]

$$Z=\frac{\sqrt{\frac{\mu_o}{\varepsilon_o}}}{2\pi\sqrt{\varepsilon_{eff}}}\ln\left(\frac{6+(2\pi-6).e^{\left(\frac{-30.666}{u}\right)^{0.7528}}}{u}+\sqrt{1+\frac{4}{u^2}}\right)$$

Effective dielectric constant εeff < 0.6% error , εr ≤ 20, 0.5 ≤ w/h2 ≤ 10 , 0 .06 ≤ h/h2 ≤ 1.5 (symbol variables as per figure 1),u=w/h2

$$\varepsilon_{eff}=\left[1+\frac{h}{h2}\left(h'-h''.\ln\left(\frac{w}{h2}\right)\right)\left(\sqrt{\varepsilon_r}-1\right)\right]^2----(2)$$

$$h'=\left(0.5173-0.1515.\ln\left(\frac{h}{h2}\right)\right)^2---------(3)$$

$$h''=\left(0.3092-0.1047.\ln\left(\frac{h}{h2}\right)\right)^2---------(4)$$

Now that as the effective permittivity is known the other dimensions i.e radius and the side arm lengths are calculated accordingly using the basic geometrical formulas.

Outer radius of ring is given by, $R_1=R_0+\frac{w}{2}$

Inner radius of ring is given by, $R_2=R_0-\frac{w}{2}$

Side arms: $L=\frac{c}{2.f.\sqrt{\varepsilon_{eff}}}$ [3],[4],[5]

In order to measure the resonant frequency, a resonator can be fed by microstrip line through gap coupling as shown in figure 2. To obtain maximum power transfer between resonator and feed line, the resonator must be matched to the feed at resonant frequency. The resonator is then said to be critically coupled to the feed.[4] If the gap between resonator and feed lines is large, then the gap capacitance is very small. Consequently, the coupling gaps do not affect the resonant frequency of resonator. This type of coupling is called loose coupling. It results in poor return loss and transmission response, thereby making it difficult to locate the resonant frequency. If the gap is reduced, the gap capacitance increases. Under tight coupling, gap capacitance becomes appreciable. This causes the major resonant frequency deviate from the true value. Tighter the coupling, larger is the deviation.[6]

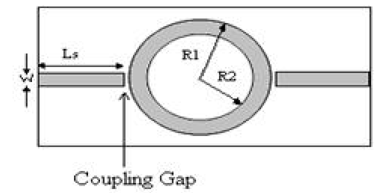

Fig 2 Ring structure

III. ELECTROMAGNETIC SIMULATION AND OPTIMIZATION

In this section we illustrate the entire simulation methods and optimizations rules derived in order to obtain Q>200. The software used for development is IE3D and HFSS-11 . These software uses different numerical solutions to solve electromagnetic problems These method includes the least-square curve-fitting technique ,conformal mapping approach , variational method , spectral domain analysis (SDA) , finite-difference time domain (FDTD) method ,and numerical methods like finite element method . Ie3d uses non uniform meshing to analyse the design whereas HFSS uses the uniform meshing. [2]

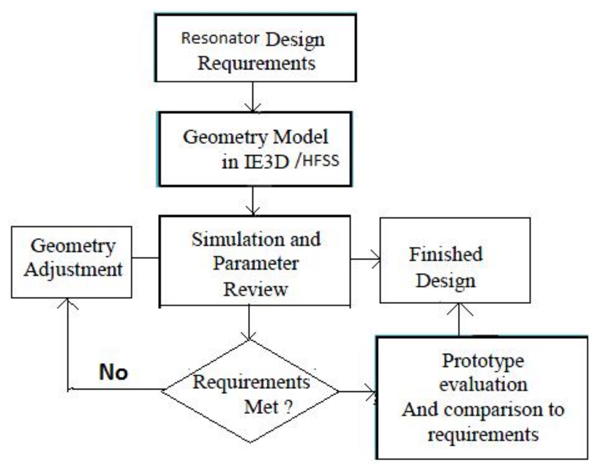

Fig 3 Simulation Flow

Ie3d	HFSS
Uniform meshing is used in the design	Non uniform Meshing is used
Used to develop patch	Used to develop entire 3d structure as per practical needs
Takes very high Mb ram for finite subtrate	Takes very less mb of ram for finite substrate
Optimization is highly time consuming and complex	Simple optimization rules are followed within less stipulated time

Diagram once developed difficult to change	Ease and flexibility to change the dimensions and parameters of the fig

It was observed that with comparatively smaller dimensions taken into consideration for the inverted ring resonator it showed large amount of shift in the resonant frequency which is not expected. Hence in order to tackle this the ring dimensions were increased and the results obtained were quite appreciable with centre frequency where as it showed less Quality factor compared to smaller ring keeping air gap constant.

The Quality Factor can be determined using simulated results using the formulas below.

$$Q = \frac{fc}{\Delta f}$$

$$fc = centrefrequency$$

$$\Delta f = f2 - f1$$

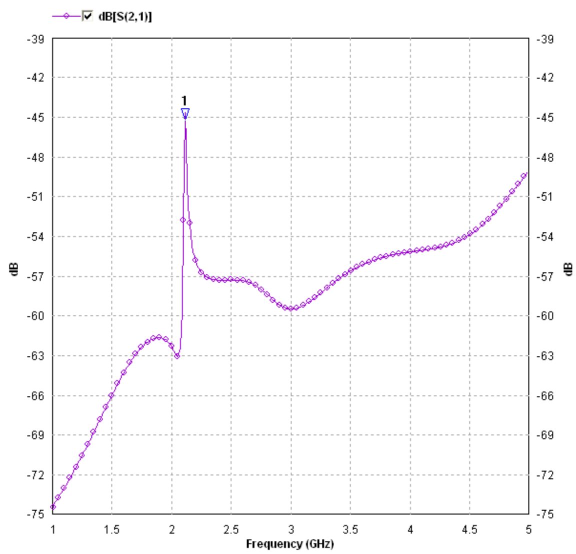

Fig 4 Simulation result for inverted ring resonator in IE3d

So finally a list of table was decided in order to develop a parametric changes of dimensions in the Q and centre frequency.

1) It was observed that with increase in the gap between the ground and the substrate the Q decreases but the centre frequency improves.
2) With decrease in coupling gap the multiple peaks appear but Q increases. With increase of coupling gap frequency deviation occurs but multiple peaks are removed . Also the Z11 doesn't fall at 50 ohms.
3) A symmetric dielectric substrate should be designed in order to obtain respectable results.

Once an optimized design is developed using IE3d the design has to be validated for practical use hence a 3d model of the design is developed using HFSS in order to check its performance on field. RT-Duroid 5880 subtrate which is considered to be the most reliable substrate and used in military product is used here in this design. The thickness of it being 1.575 mm. [5]

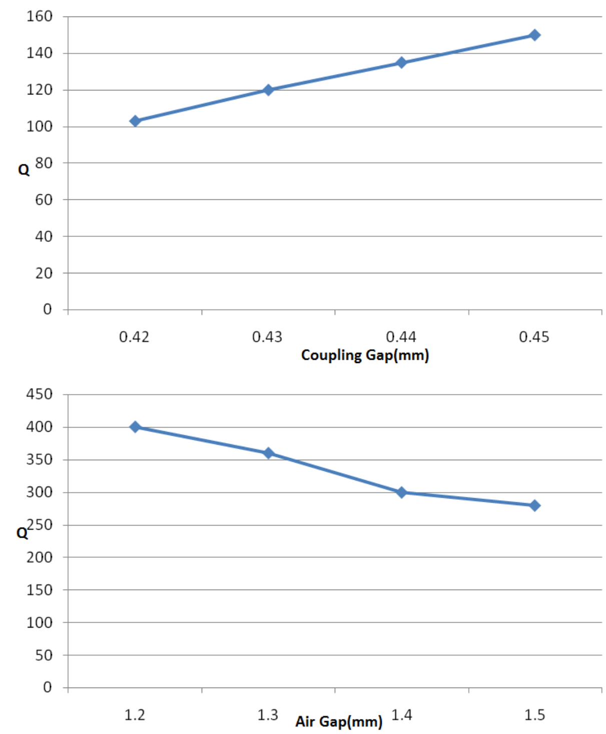

Fig 5 Effect of airgap and coupling gap on Q

Similar conditions were given to HFSS considering all the environmental losses and exact 3d structure and the S21 readings gave Q as 280 which was quiet appreciable after optimization at the resonant frequency of 2.25 Ghz designed theoretically for 2.45Ghz.

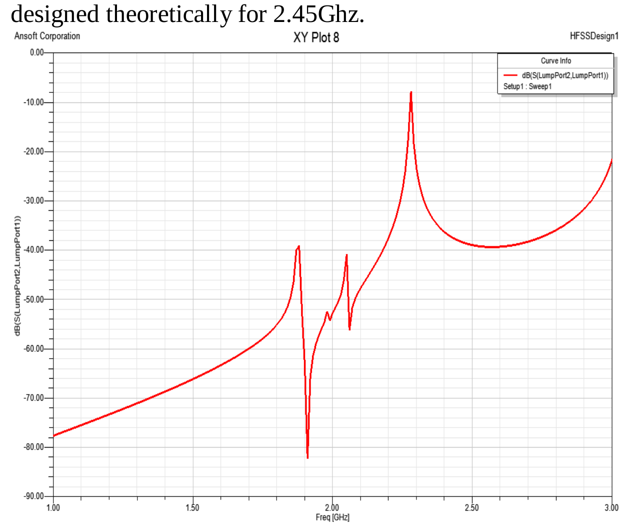

Fig 6 Simulation results for Inverted Ring resonator in HFSS

Entire designing of the inverted resonator structure was developed in matlab7 for providing the quick and accurate calculations and design. Designing the code appropriately the W, h, h2, ε_{eff} can be calculated.

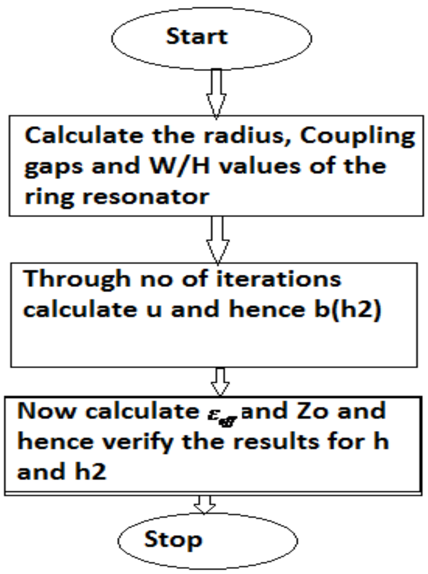

Fig 7 Flow chart for matlab design

IV. Results

The final optimized result obtained were finalized for the following dimensions. It was observed that with these dimensions all the parameters for considerations were critical and hence considered appropriate.

Air Gap	1.5mm
Aluminium Ground Width	2mm
RT Duroid(substrate width)	1.575mm
Side Aluminium casing(other than side arms)	2mm
Coupling Gap	0.39mm
Box Length	95mm
Box Width	95mm
Ring inner Radius	14.95mm
Ring outer Radius	22.51mm
Side Arm Length	24.6mm
Side Arm Width	7.56mm

Dimension Details

V. Conclusion

Microstrip inverted structure is difficult for development because of mechanical complexities. Optimization of Q and F achieved using both HFSS & IE3D software for physical dimensions considering all practical issues. Basic prototype of structure is developed. This inverted microstrip resonator is tested using Network Analyzer HP 8714ET. Practical results are within 2% of error for Q & F. These result can be improved using precise development process where losses can be further reduced.

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Author's Profile

Nishant Mittal Pursuing Electronics and telecommunication Final year in MAEERS MIT, Pune. He has published many articles in electronics for you and have interest in Computational electromagnetic, ANN and embedded systems. He wasfinalist in AVISHKAR 2011 university level project competition. Present research work includes design of suspended resonators, efficient cost pcb designing techniques
Mail id: engnishantmittal@yahoo.com.Address: Kathmandu, Nepal

Rutika Lahoti Pursuing Electronics and telecommunication She is final year in MAEERS MIT Pune. She has interest in embedded systems and electromagnetic and is working with whirlpool india.She was finalist in AVISHKAR 2011 university level project competition.
Mail id : rutikalahoti@gmail.com
Address: Akola,Maharashtra,India

Savita Kulkarni Pursuing PHD in Electronics engineering.She is working as associate professor in MAEERS,MIT,Pune since 1992.She is working on Electrical Characterization of petroleum products at microwave frequencies She is author and co-author of about 16 technical papers and is IEEE and IETE member. She has obtained provisional patent in the above research subject.
Mail id: Savkulkarni@yahoo.co.in . Address: MIT,Pune .

Dr. Madhuri Joshi Is a Doctrate in Computer Engineering . She is working as Head in Computer Engineering Department, Govt. College of Engineering and Research, Awasari (Khurd), Tq. Ambegaon, Dist - Pune (M.S. India) Pin- 412 405. She has published over 30 international papers and her area of research is soft computing.
Mail id: madhuris.joshi@gmail.com