Design of Complementary Spiral Resonator

Hridesh Kumar Verma[1], Atul Kumar Singh[2], Jayant Gupta[3], Alind Johari[4]
[1,2,3,4] Department of Electronics and Instrumentation
Galgotias College of Engineering and Technology, Greater Noida-201306

Abstract-In this paper, a high-Q resonator is presented and its structure is in the shape of spiral, hence Complementary Spiral Resonator. The measurement of the complementary spiral resonator itself shows that a higher loaded quality factor is provided as compared to the Double H-Shaped Resonator. The resonator was designed to operate at a frequency of 10 GHz and the phase noise performance of the system is observed. The measurement result shows the phase insertion noise of -15.517 dB and the return loss of around -19dB.

Index Terms **- Metamaterial, DHMR, high-Q, low phase noise.**

I. INTRODUCTION

In most of the cases, microwave oscillators are used for the conversion of frequency and carrier generation, and extensively used in every modern radar and satellite communication systems. These use an active device, such as transistors and diodes to convert the direct current (DC) to a sinusoidal steady state signal (carrier). High quality factor (Q) resonators are essential for low phase noise oscillators. Phase noise is amongst the most vital parameters in a RF system because it determines the overall performance of the system.

The dielectric resonators are promising elements for these applications. However they have certain shortcomings, they have a three-dimensional (3-D) circuit and they are bulky in sizes. Thus they are limited to be used be used in the systems such as System on Chip (SOC) and MMIC (Monolithic Microwave Integrated Circuits) realizations and are not suitable for production over large scale.

Low Phase Noise microwave oscillators are a significant part of wireless communication and radar systems because the low phase noise is key performance parameter responsible for the enhancement of the overall systems. To achieve low phase noise methods such as dielectric resonator (DR) that adopts high –Q resonators has been used. But being bulky, non-planar structure and expensive they are not suitable for microwave monolithic integrated circuit (MMIC). To counter this problem several planar resonators and filters have been suggested such as hairpin resonators.

In the recent years, there have been abundant attempts to reduce the phase noise of the planar oscillators, which have certain advantages for low cost and better reliability. Nevertheless, their phase-noise characteristics are substandard due to the poor Q factor of the planar type resonator.

II. DOUBLE H- SHAPED METAMATERIAL RESONATOR

A. Theory and Layout of DHMR.

The double H shaped metamaterial resonator represents electromagnetic character by dipole which is parallel with incident E-field. They have high Q-factor as reinforced a capacitive reactance by the intaglio compared with the embossment in microstrip line.

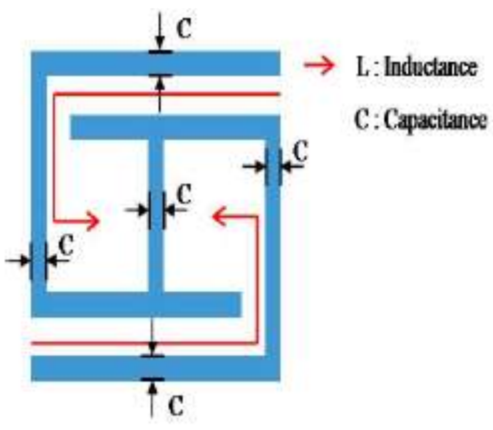


Fig.1 Schematic of a DHMR

B. Fabrication and Experimental Result

The Layout of a Double H-Shaped Metamaterial Resonator is shown in figure 1. The Double H-Shaped Metamaterial resonator was fabricated on a Teflon substrate with a dielectric of 3.2

Length of single cell	3 mm
Breadth of single cell	3mm
Width of strip	0.3 mm
Substrate material	Teflon (dielectric 3.2)

Table I Information for the dimension of DHMR.

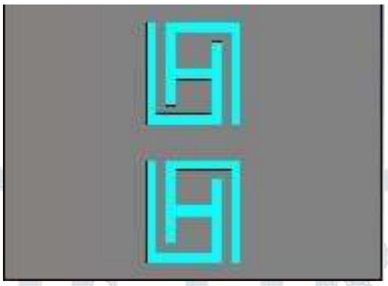
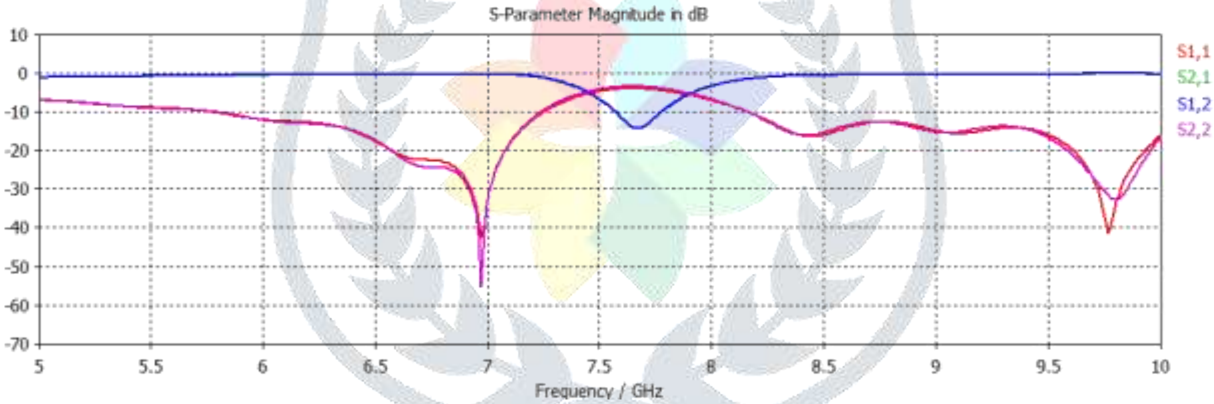


Fig. 2 Simulated DHMR in CST

Fig 3. Shows the simulated result for the Double H-Shaped Metamterial Resonator. From the Figure the simulated Q_L of around 26 is obtained at a resonant frequency of about 7 GHz respectively the return loss is around -41 dB and phase insertion loss is around -



14 dB.

Fig.3. Simulated result for DHMR

III COMPLEMENTARY SPIRAL RESONATOR

A. Theory and Layout of a Complementary Spiral Resonator

The complementary spiral resonator is a slot resonator etched in a metallic layer which is depicted in Fig. 4(a). Here d is the gap between conductors and g is the width between the dielectrics (εr). And l_1 and l_2 are electrical length and breadth of the complementary spiral resonator.

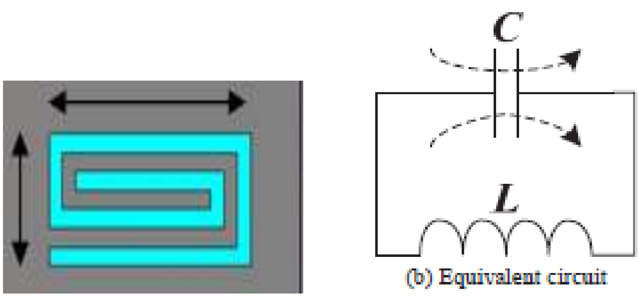


Fig. 4. Schematic of the Complementary Spiral Resonator

From the figure, the C and L are the capacitances and inductance corresponding to the Complementary Spiral Resonator. Hence, the inductance L and capacitance C determine the resonant frequency ω_0 of the complementary spiral resonator. Also, the inductance *L* of the CSR is larger than the inductance of the hair-pin resonator. The equation (1) showsthe frequency of a CSR

$$f_{CSR} = 1/2\pi\sqrt{LC} \qquad (1)$$

B. Fabrication and Experimental result

The layout of CSR is shown in Fig. 4(a). The complementary Spiral Resonator was fabricated on a Teflon Substrate which has the height of 0.54mm, conductor thickness of 0.18mm, and the dielectric of 2.54. Table II shows the electrical lengths and widths of the CSR.

Information for the dimension of the CSR

dimensions		values [mm]
lengths	l_1	2.27
	l_2	1.05
widths	g	0.15
	d	

Table II

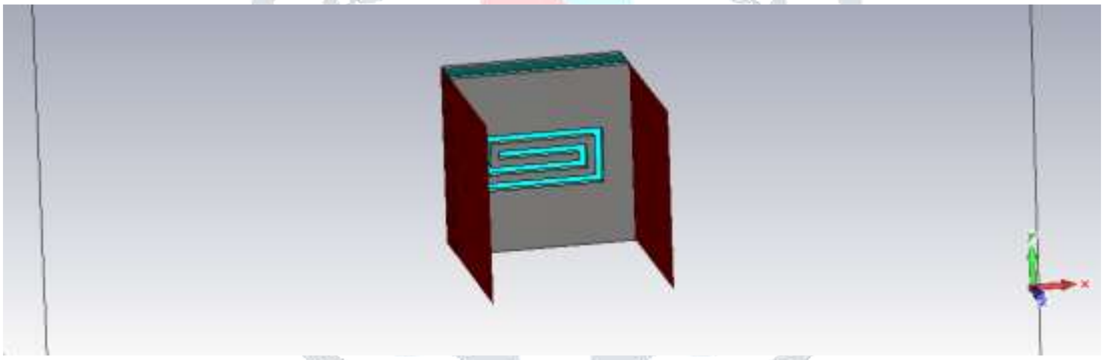


Fig. 5 Simulated Complementary Spiral Resonator in CST.

Fig. 6 shows the simulated results for the high-Q_L Complementary Spiral Resonator. From the figure the simulated Q_L of 94 is obtained at a resonant frequency of 10.5 GHz, respectively. The loaded quality factor can be calculated from the equivalent circuit shown in Fig. 2(b) as follows,

$$Q_L = \omega_o \frac{R \cdot 2Z_o}{R + 2Z_o} C \qquad (2)$$

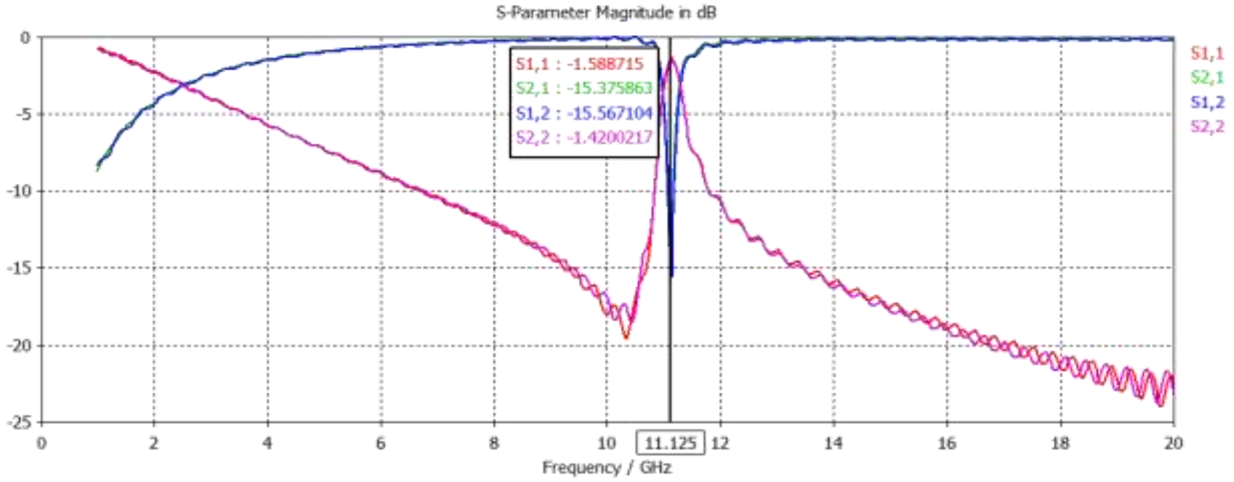


Fig. 6 Simulated Results for the Complementary Spiral Shaped Resonator.

The loaded quality factor can also be computed from the measured reflection coefficient, S_{11}as described in Fig. 7.

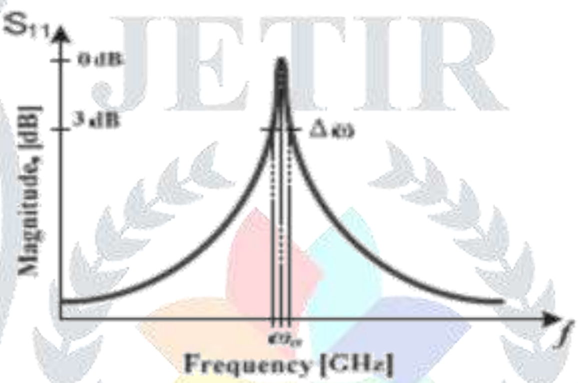


Fig. 7 Definition of the loaded quality factor measurement.

The loaded quality factor corresponds to the 3dB bandwidth of S_{11} given by,

$$Q_L = \omega_0/\Delta\omega \, . \qquad (3)$$

Since the quality factor has great effect on the phase noise performance of the oscillator as shown in the equation (4), the suggested resonator is expected to provide low phase noise performance.

$$L\{\Delta\omega\} = 10\log\left[\frac{2FKT}{P_s}\left\{1+\left(\frac{\omega_o}{2Q\Delta\omega}\right)^2\right\}\left(1+\frac{\Delta\omega_{1/f^3}}{|\Delta\omega|}\right)\right] \qquad (4)$$

The simulation has been carried out by the Computer Simulation Technique (CST) Microwave Studio. The Complementary Spiral Resonator is observed to have a high quality factor.

A. CONCLUSION

Parameters	CSR	DHMR
Substrate material	Teflon	Teflon
Dielectric constant	2.54	3.2
Phase insertion loss	-15.517 dB	-14 dB
Return loss	-19 dB	-41 dB
Quality factor	94	26
Resonating frequency	10.5 GHz	7 GHz

Table III

In this paper, a CSR (Complementary Spiral Resonator) has been designed and its output characteristics have been observed and compared with DHMR. The Complementary Spiral-Resonator provides a sharp band- rejection characteristics and a high loaded quality factor (Q_L). The phase insertion loss for the CSR is around -15.517dB and the Return Loss is around -19 dB and the 3dB bandwidth of the CSR is around 1GHz and the loaded quality factor of the CSR is around 94. In this the CSR improves the loaded quality factor leading to the low phase noise oscillator.

The resonator is designed to operate at 10GHz. Due to entirely planar structure the proposed resonator can also be adequate in MMIC (Microwave Monolithic Integrated Circuit) oscillator applications for a low cost and low phase noise performance.

B. REFERENCES

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