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A Comperative Study on Design, Development and Performance Analysis of RF Resonators for Low Phase Noise Oscillator Applications

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Abstract- In this paper, we have analysed the performance of various resonator structures used in VCO. Phase noise, noise figure, return loss and insertion loss of various resonator structures are analysed. We found the resonator structure reported by Jonghoon Choi, Morteza Nick and Amir Mortazawi, titled "low phase noise planar oscillators employing elliptic response bandpass filters" is having better results of phase noise and noise figure. The paper mentioned above has lowest phase noise performance for an X-band planar microwave oscillator. The paper summarises improvement of 6.5 dBc per Hz phase noise and 3.5 dB at 100 KHz and 1 MHz offset frequency. After analysis of various papers, it is found that complementary spiral resonator improves the loaded quality factor leading to the low phase noise of oscillator. Hairpin shaped resonator provides low phase noise, low DC power consumption, high output power and excellent harmonic suppression.

I. INTRODUCTION

A resonator is a device or system that exhibits resonance or resonant behaviour, that is, it naturally oscillates at some frequencies, called its resonant frequencies, with greater amplitude than at others. The oscillations in a resonator can be either electromagnetic or mechanical (including acoustic). Resonators are used to either generate waves of specific frequencies or to select specific frequencies from a signal.

The resonator is an integral component in most electron paramagnetic resonance (EPR) spectrometers. It is not strictly necessary to achieve resonance, however in practice it is only the strongest of paramagnetic signals and very high frequency systems (where resonator geometries become difficult to engineer) that obtain an appreciable signal without one.

The term resonator is most often used for a homogeneous object in which vibrations travel as waves, at an approximately constant velocity, bouncing back and forth between the sides of the resonator. The material of the resonator, through which the waves flow, can be viewed as being made of millions of coupled moving parts (such as atoms). Therefore they can have millions of resonant frequencies, although only a few may be used in practical resonators.

There are we discuss different types of resonator:

1. *Complementary split ring resonator*
2. *Varactor loaded split ring resonator*
3. *Planer oscillator employing elliptical response band pass filter*
4. *Hairpin shaped resonator*
5. *Microstrip elliptical patch resonator*

Phase noise is Short-term stability is an important quality in sine wave outputs for many military and broadcast applications. Short-term stability refers to the movement of the zero crossings of a signal relative to those of a reference frequency standard, measured over observation intervals that are typically shorter than one second. When measured in units of time, in a broad bandwidth, it is commonly called jitter. When measured in units of phase, in a 1 Hz bandwidth centered at specific frequencies, it is called phase noise.

II. COMPARISON OF DIFFERENT RESONATORS

These resonators with amplifiers used as oscillators show different performance parameters like phase noise, different method used at different oscillations frequencies, different figure of merits etc.

YEAR	AUTHOR	METHOD USED	PHASE NOISE (dBc per Hz)	FREQ.(GHz)	FOM (dBc per Hz)
2014	ByeongTaek Moon, Noh HoonMyunk	Hair pin resonator using R/L handed TL	-120.5	4.95	-206.3
2011	Ki Cheol Yoon, Hyunwook Lee, et al.	Complementary spiral resonator	-123.82	10	
2009	Jaewon Choi, ChulhunSeo	High quality meta material TL based on complementary spiral resonator	-124.43 to -122.60	5.73	-204.28
2009	Jonghoon Choi, Morteza Nick, Amir Mortazawi	Elliptic response band pass filter	-143.5	8.05	
2007	Jaewon Choi, ChulhunSeo	Tunable metamaterial TL based on varactor loaded split ring resonator	-110.5 to -108.0		-6.7

III. DESIGN OF VARIOUS RESONATORS

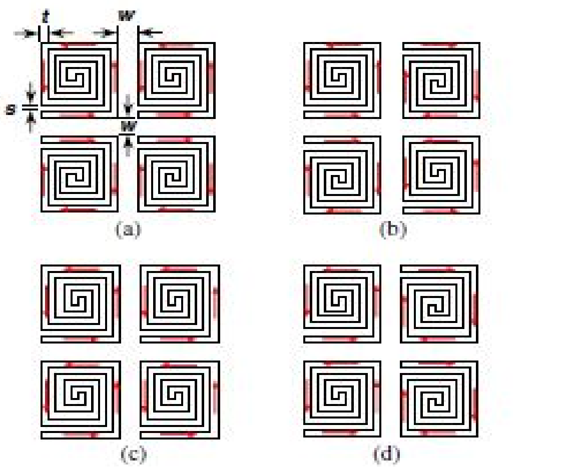

Figure 1: Four different current directions between CSR's etched on ground plane

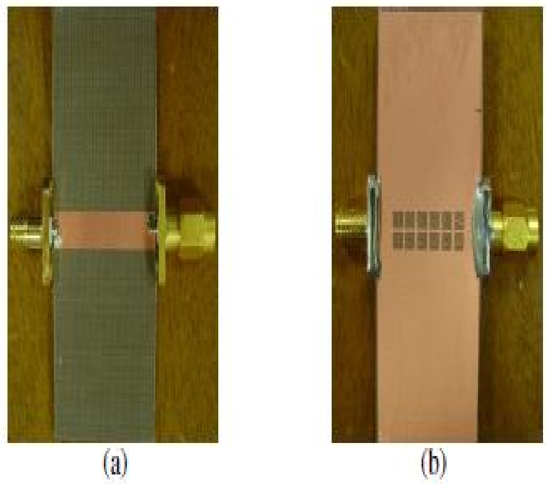

Figure 2: Fabrication of high Q metamaterial TL based on CSR's (a) Top view (signal plane), (b) Bottom view (ground plane)

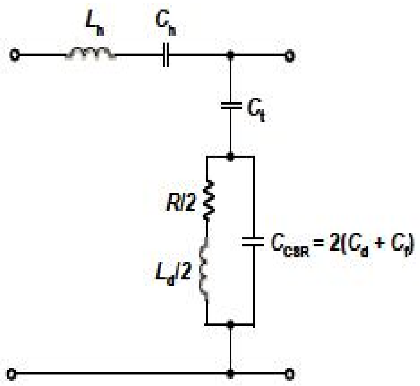

Figure 3: Equivalent circuit model of high Q-metamaterial TL based on six unit cell pairs of 3 turn of CSR's etched on ground plane.

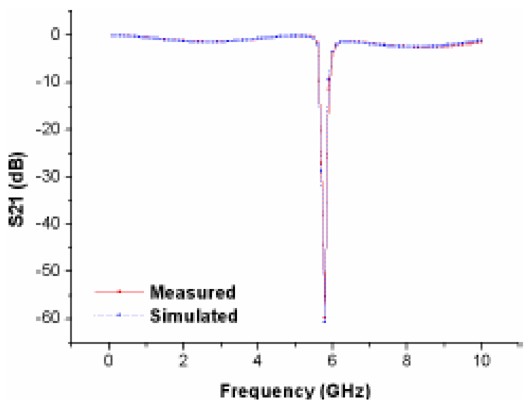

Figure 4: Simulated and measured result of resonance property of high Q metamaterial TL based on CSR's

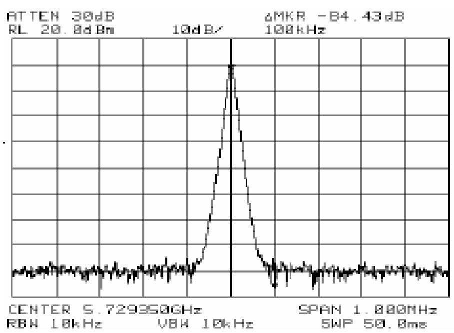

Figure 5: Measured phase noise property of proposed VCO using high Q metamaterial TL based on CSR's

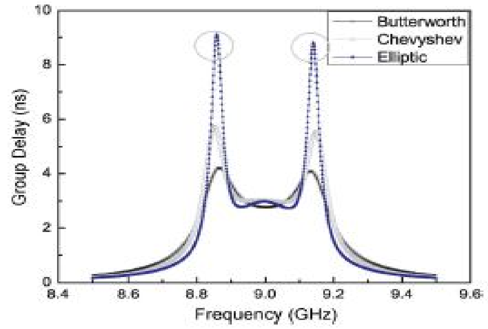

Figure 6: Comparison of group-delay response butterworth, chebyshev and elliptic bandpass filters

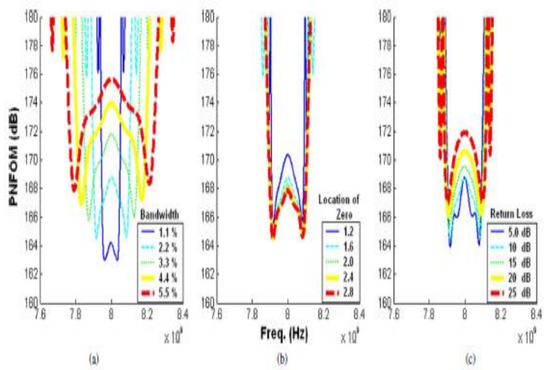

Figure 7: PNFOM versus frequency for different (a) BWs, (b) normalized location of transmission zeros, and (c) return losses of four-pole elliptic filters.

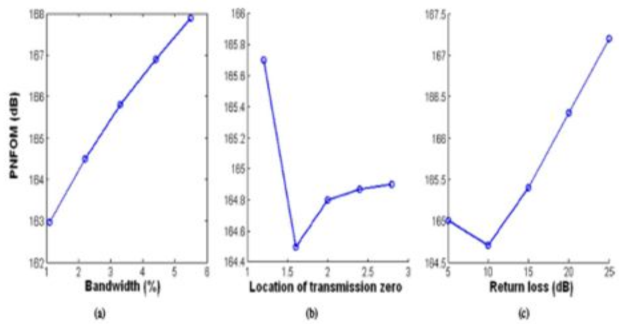

Figure 8: Minimum PNFOM versus:(a) passband BW, (b)normalized location of transmission zero, and (c)return loss of four -pole elliptic filters

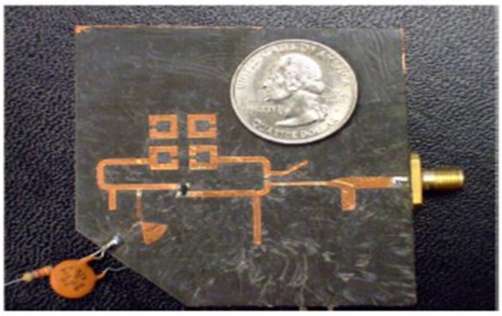

Figure 9: Fabricated X-band SiGe HBT oscillator employing the four-pole elliptic bandpass filter

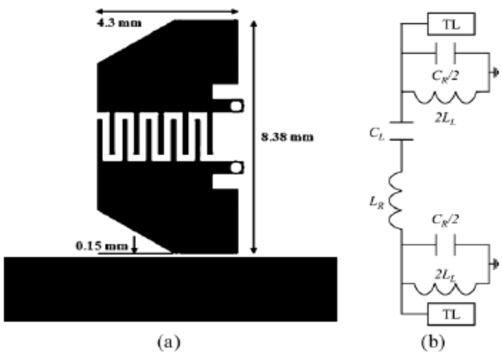

Figure10: Proposed HSR (a) layout and (b) equivalent circuit

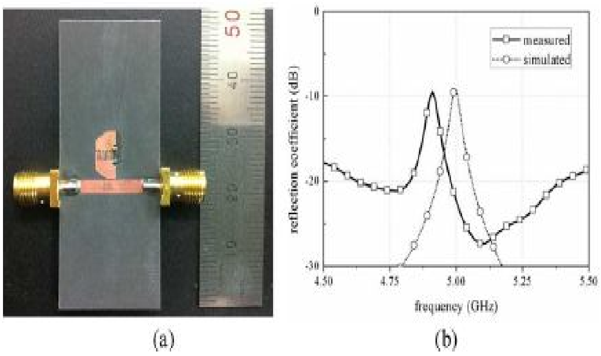

Figure 11: Fabrication (b) Measured and simulated reflection coefficient.

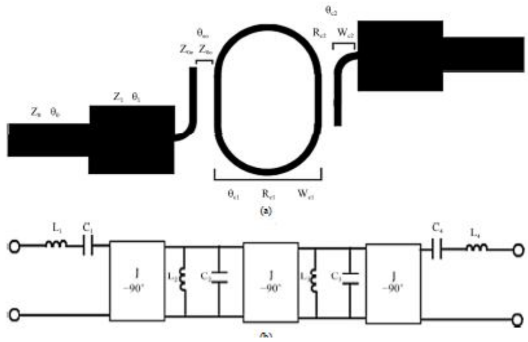

Figure 12: Schematic and equivalent circuit of the bandpass filter (a) Schematic layout: (b) Equivalent circuit

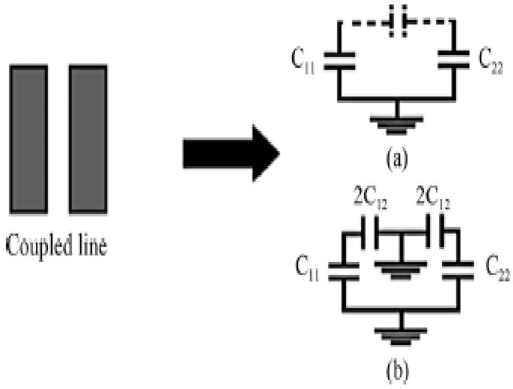

Figure13: Coupled line and the resulting equivalent capacitance networks (a) Even mode; (b) Odd mode

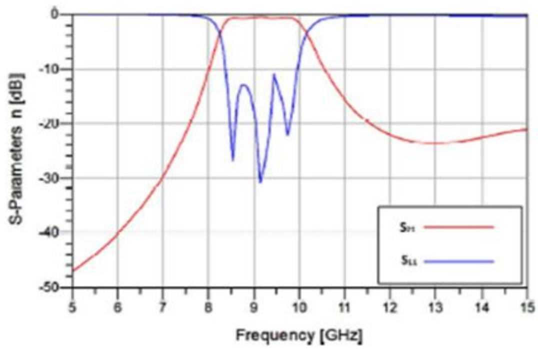

Figure 14: The simulated insertion loss (S21) and return loss (S11) of the proposed filter

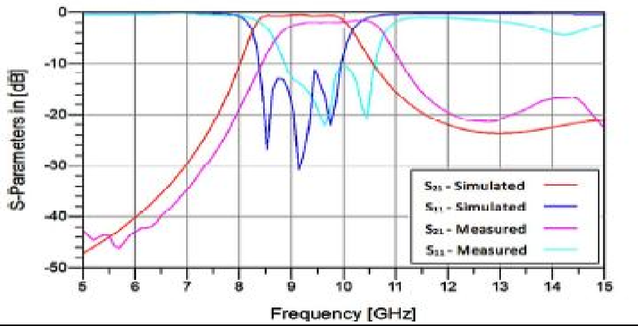

Figure 15: Comparison between measured and simulated result

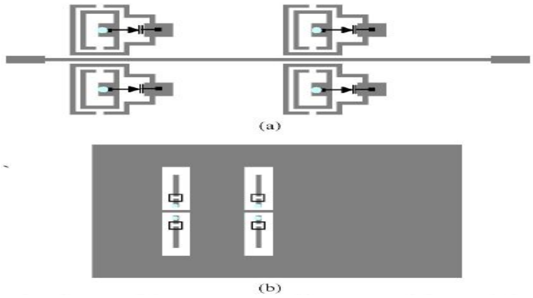

Figure 18: Layout of the two-stage tunable metamaterial transmission line (a) Top view (b) Bottom view

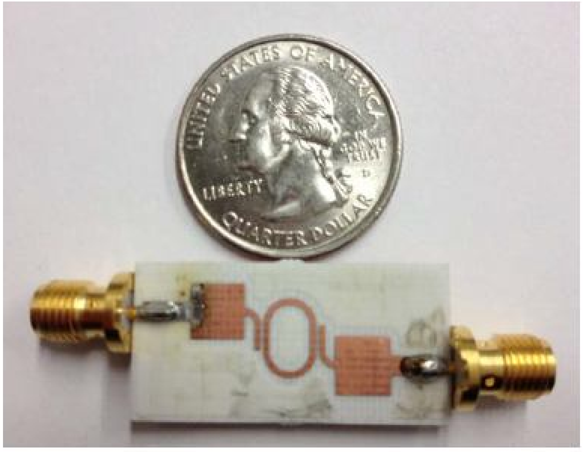

Figure16: Fabricated elliptical patch resonator bandpass filters

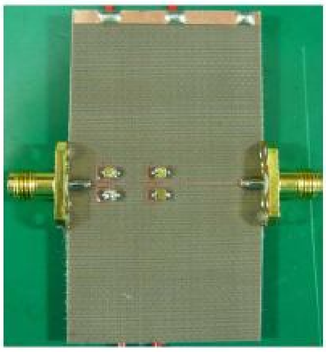

Figure 19: Fabrication of the two -stage tunable metamaterial transmission line

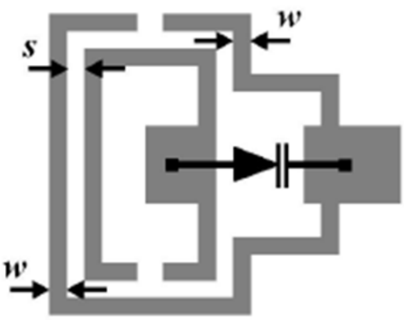

Figure 17: Tunable varactor-loaded SRR (VLSRR)

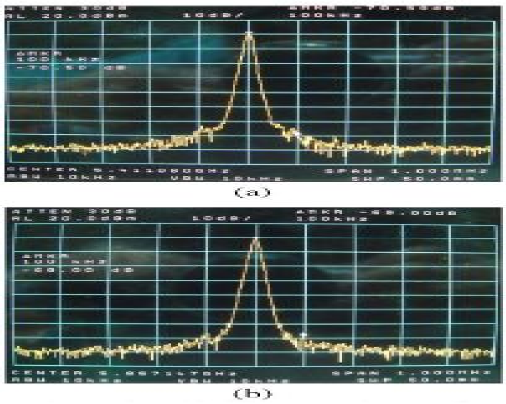

Figure 20: Measured frequency response (a) 5.37GHz (b) 5.87GHz

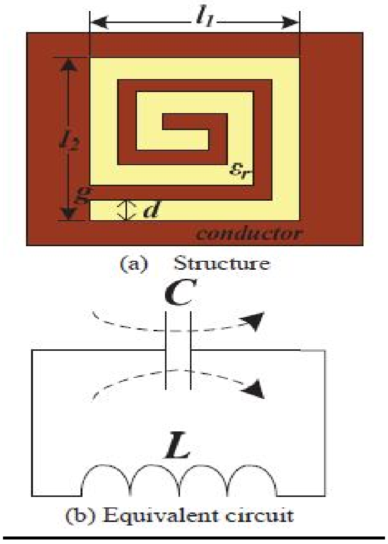

Figure 21: Schematic of the complementary spiral resonator

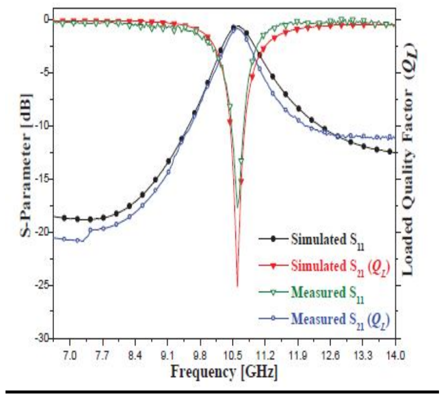

Figure22: Simulation and measurement result for the CSR

IV. RESULT COMPARISON OF VARIOUS RESONATORS

On studying the various resonators and comparing them, we conclude that the basic aim of using various resonators is to reduce the phase noise. This can be very well understood after studying resonators like complimentary spiral ring resonator, varactor loaded spiral ring resonator, complimentary spiral ring resonator in x-band low phase noise oscillator, elliptic response of band pass filters in low phase noise oscillators, hair pin shaped resonator and microstrip elliptical patch resonator filter.

In case of low phase noise vco using high quality metamaterial transmission line based on complimentary spiral resonator phase noise is between -124.43 to -122.60 dBc per Hz at 100 KHz, tuning range of VCO 5.73 to 5.85 GHz [1]. Where as in low phase noise vco using tunable metamaterial transmission line based on varactor loaded split ring resonator phase noise is between -110.5 to -108.0dBc per Hz at 100 KHz, tuning range 5.411 to 5.857 GHz [2]. In X-band low phase noise oscillator using complimentary spiral resonator phase noise is -123.83 dB per Hz at 1MHz offset [6]. In low phase noise planar oscillator using elliptic response band pass filter low phase noise is -143.5 dBc per Hz at 1MHz offset [3]. In hair pin shaped resonator phase noise studied is -120.5 dBc per Hz at 100 KHz [4].

In [1] resonance properties and inherent saturation of Q-values is done by varying the width of center line on signal plane, dimension of CSR's and increasing the number of unit cell pairs of CSR's, whereas tunable metamaterial transmission line based on varactor loaded split ring resonator the negative effect permeability is provided by VLSRR in a narrow band above resonance frequency. Compared with VCO using conventional SRR, the widened tuning range and phase noise (4 times) has been reduced, PTFN has improved. In X-band low phase noise oscillator using complimentary spiral resonator improves loaded quality factor leading to low phase noise oscillator. Measurements show that this resonator provides a higher loaded quality factor to hair pin resonator. In low phase noise planar oscillator using elliptic response band pass filter phase noise (-143.5dBc per Hz at 1MHz offset) is lowest phase noise performance for an X band planar microwave oscillator. In this filter, optimisation techniques for low phase noise oscillator design are introduced. In hair pin shaped resonator high quality factor is obtained. An electric field is concentrated on composite right handed transmission line (CRLH TL) and then the CRLH TL gives a low loss, reason slow wave effect.

V. CONCLUSION

In this paper, we have analysed the various parameters such as phase noise, noise figure, return loss and insertion loss. We conclude that paper presented by"Jonghoon Choi, Morteza Nick and Amir Mortazawi", titled "low phase noise planar oscillators employing elliptic response bandpass filters" is having better results of phase noise and noise figure.To achieve best phase noise performance from oscillator feedback loop is presented. In this paper we conclude that the aim of every resonator is to reduce the phase noise and enhance the tuning range. Optimization technique gives the optimum values for the order, bandwidth, location of transmission zero and return loss of filter.

In paper [1] the topology having same horizontal current direction and other vertical current direction is studied. 6 unit cell pairs of 3-turns CSR's is considered to realize high quality meta material transmission line based on CSR's. Geometry data of resonator is t=s=0.2mm, w=0.7mm. Miniaturization of resonator and property of low phase noise is achieved by enhancing couplings between inside and outside lines of CSR's and broadside couplings between centre line on signal plane and CSR's etched on ground plane.

In paper [2], two stage VSLRR is studied. Comparing it with VCO using conventional SRR the widened tuning range and the reduced phase noise has been 4 times (338 MHz) and PTFN is improved to 17.8 dB.
In paper [6] CSR provides sharp band rejection characteristics and high loaded quality factor. It also has stop band rejection characteristics. The X-Band oscillator using this resonator is implemented with HMIC technique. Due to entirely planar structure, the proposed resonator can be easily used in MMIC oscillator.CSR improves the loaded quality factor leading to the low phase noise of the oscillator.

The oscillator phase noise is reduced a great deal. Filter optimization technique is applied to a 4-pole bandpass elliptical filter [3]. To achieve best phase noise performance from oscillator feedback loop is presented. This technique determines optimal values for the order, bandwidth, and location of transmission zero and return loss of filter. On a Rogers RT/Duroid 5880 substrate with Size HBT packaged transistor as active device. This leads to improvement in phase noise by 6.5 and 3.5 dB at 100KHz and 1MHz offset frequency. In paper [4] oscillator provides low phase noise, low DC power consumption, and high output and excellent harmonic suppression is given by the oscillator. Planar structure of oscillators gives fully integration in MMIC with low cost.

In paper [5] it is proposed that centre frequency can be easily changed to modify the bandwidth of filter. Here order of elliptical patch resonator can be increased. Three types of different orders of the same design are +compared. Its advantage is, its provide high frequency in design. The one variable modified is spacing in the coupled line. The size of elliptical patch resonator changes the centre frequency. The return loss and insertion loss of measurements are in agreement with simulation result.

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