Study of Hairpin Shaped Resonator and Performance Analysis

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Abstract- This paper illustrates a comparison between various circuits based on the hair pin resonators. The aim of this report is to demonstrate the feasibility of a miniaturized metamaterial resonator, these have potential use in multiband microwave devices such as cell phone antennas. The performance of the various circuits taking hairpin resonator as a unit cell is observed. The circuits taken into consideration uses various substrate materials with different dielectric constants. The performance of the various circuits taking hairpin resonator as a unit cell is observed by comparing various parameters.

INTRODUCTION

With the ever increasing demand in wireless communication systems, being the key component, minimizing the size of filter circuit and enhancing the performance of circuits is now one of the biggest challenges in the current market. Designs such as hair pin resonators, ring resonators were then introduced for such problems.

Hairpin resonators became widely famous because of its compactness and its ease of fabrication. These were developed by bending a common microstrip resonator into a pattern shaped "U" thus named as hair pin resonator

Tunable Hairpin Resonator Based on Liquid Crystal by A. Mirfatah and J. J. Laurin [8] was a fine approach to meet this demand. Further Cross-Coupled Microstrip Hairpin Resonator Filters were illustrated by Jia-Sheng Hong and Michael J. Lancaster [2] in 1998. Recent advancement in technology has led to the development of High Q resonators as reported by Ki-Cheol Yoon and his colleagues [3]; they designed an X-Band Low phase noise oscillator by using a complementary Spiral resonator. Another design for Low Phase Noise Oscillator was developed by Byeong-Taek Moon and Noh-Hoon Myung [4] which was also based on hair pin shaped resonator but using a composite left/right handed transmission line.

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.

DESIGN AND ANALYSIS OF VARIOUS CIRCUITS:

I. TUNABLE HAIRPIN RESONATOR BASED ON LIQUID CRYSTAL

J.J. Laurin and A. Mirfatah discussed about a novel tunable resonator which uses liquid crystal as a dielectric is proposed. Due to the bias-dependent permittivity of an anisotropic nematic liquid crystal entrenched in the resonator's multilayer substrate, a differential phase shift of 180° in the reflection coefficient is predicted in X band. The resonator is sputter layered on the bottom face of a 5mm alumina substrate.

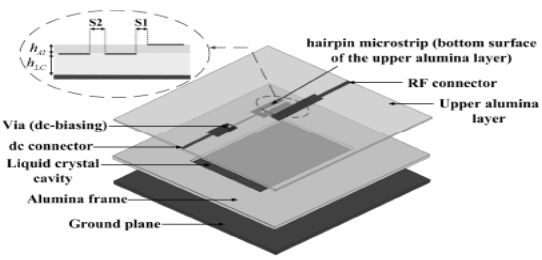


Fig 1. The structure of hairpin resonator based on liquid crystal

In order to attain the best possible performance, following guidelines were followed in the design of the multilayered structure:

- Maximize the percentage of resonator's RF energy storage in the liquid crystal volume so as to increase tenability, this is achieved by having the printed hairpin directly in contact with the LC
- Avoid having RF and DC connection ports in contact with the LC container to prevent leakage and spills.

ANALYSIS AND RESULT:

Figure 2 represents simulated and measured return loss at the coaxial input port over the frequency range of interest. We have studied a new tunable hairpin resonator implemented with nematic liquid crystal for an operating frequency near 10 GHz. According to the experimental results, at 9.24GHz a phase tuning range of 177° was achieved. However the return loss levels in biased and unbiased states are high due to absorption in the liquid crystal: -16dB (0V) and -12.5dB (32V).

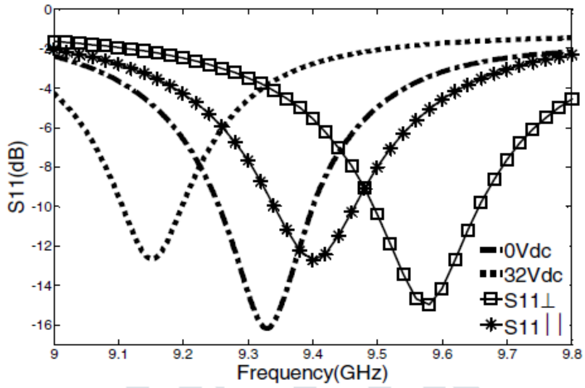


Fig 2. Experimental and predicted return loss.

II. CROSS-COUPLED MICROSTRIP HAIRPIN-RESONATOR FILTER

Jia-Sheng Hong and Micheal J. Lancaster discussed a four-pole cross-coupled filter of this type is designed and fabricated. It was fabricated on a RT/Droid substrate with a relative dielectric constant of 10.8. Applications of microstrip hairpin resonators lead to a new class of cross-coupled microstrip bandpass filters. The cross-coupled filters are admired because they exhibit ripples in both passband and stopband which can improve both frequency selectivity and bandpass loss. This property is useful in narrow-band filters where the passband insertion loss is strongly related to the number of resonators.

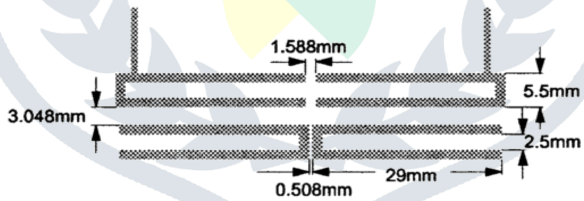


Fig 3. Layout of the four-pole cross-coupled hairpin-resonator bandpass filter

They have 2.07% fractional bandwidth at 965 MHz on an RT/Duroid substrate with r= 10.8 and a thickness h = 1:27 mm. The resonators are almost identical for this narrow-band filter.

ANALYSIS AND RESULT:

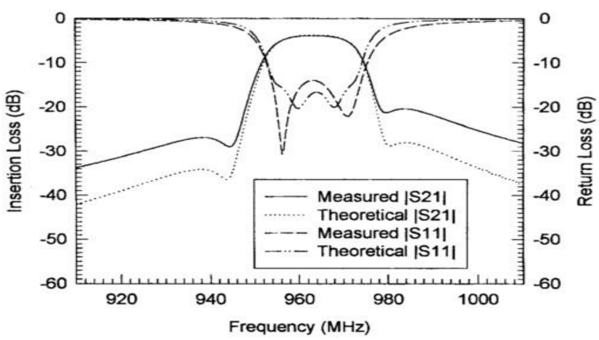


Fig 4. Measured and theoretical response
of the filter

The filter was fabricated on an RT/Duroid substrate with a relative dielectric constant of 10.8 and a thickness of 1.27 mm. The passband insertion loss is 3.8 dB and the return loss is -33 dB approximately. This is largely due to the conductor loss for a resonator Q_0 around 250. The two transmission zeroes near the cutoff of the passband can clearly be recognized, which would result in higher attenuation if the resonator Q_0 were larger.

III. X-BAND LOW PHASE NOISE OSCILLATOR USING A COMPLEMENTARY SPIRAL RESONATOR

Ki-Cheol Yoon and his colleagues proposed a high-*Q* resonator and it is applied to the design of an X-band oscillator. The measurement of the resonator itself shows that it provides a higher loaded quality factor compared to the hair-pin and complementary spiral-resonator. The oscillator is designed to operate at 10 GHz using the complementary spiral resonator to compare the phase noise performance. The measurement results show the output power of 9.80 dBm and phase noise of -123.82 dB/Hz at 1 MHz offset, respectively. It was fabricated on a Teflon substrate with a relative dielectric constant of 2.52.

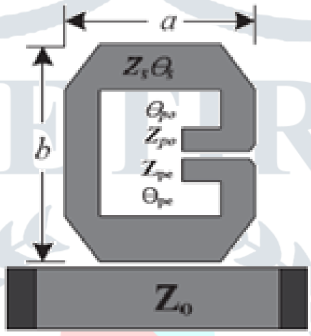


Fig. 5 Schematic of Hair Pin Resonator

TABLE I
Dimensions of the hair-pin resonator

length	value [mm]	Parameter	
		Dielectric constant	Frequency [GHz]
a	4.10	2.52	10.0
b	3.45		

The resonance conditions of hair-pin resonators can be obtained by the ABCD matrix, which expresses a transmission line and a capacitor. Table I shows the experimental results for the loaded quality factor.
LAYOUT OF A SPIRAL OSCILLATOR

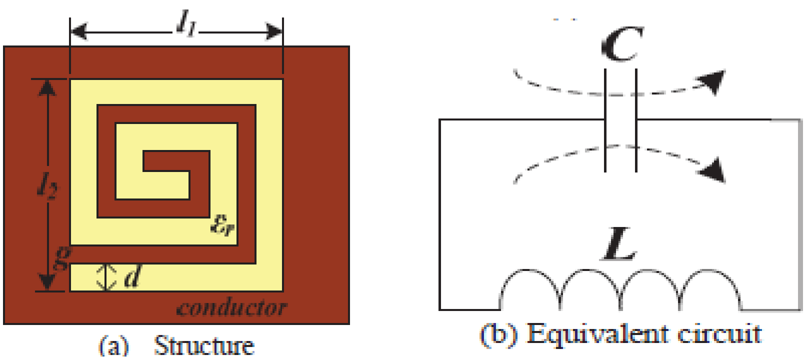


Fig 6. Schematic of the complementary spiral resonator

SIMULATION AND MEASUREMENT RESULT:

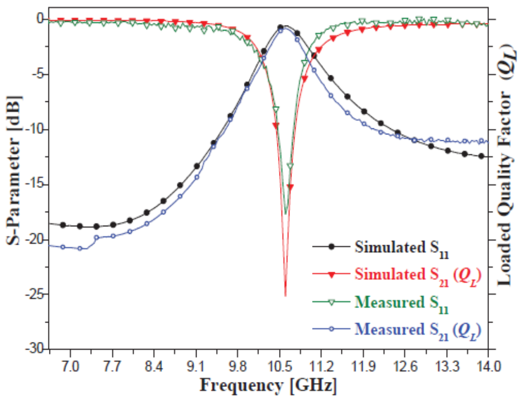


Fig 7. Simulation and measurement result for CSR

Fig. 7 shows the experimental results for the high-*QL* CSR .From the figure, the simulated QL of 198 and the measured *QL* of 118 is obtained at the resonant frequency of 10.6 GHz, respectively. The measured return loss is -18dB and phase insertion loss is 0.4dB approximately

IV. LOW PHASE-NOISE OSCILLATOR BASED ON A HSR USING CRLH TRANSMISSION LINE

Byeong-Taek Moon and Noh-Hoon Myung designed a low phase-noise microwave oscillator based on a hairpin-shaped resonator (HSR) uses a composite right/left-handed transmission line (CRLH TL). The HSR consists of the conventional transmission line (CTL) and the CRLH TL. In order to obtain the high- factor, an electric field is concentrated on the CRLH TL, and then the CRLH TL provides a low loss due to a slow wave effect. The HSR has a very compact size of 0.105 λg x 0.19 λg. An oscillator based on the HSR was designed, fabricated and measured. At the oscillation frequency of 4.95 GHz, the measured phase noise is 1290.5 dBc/Hz at 100 kHz offset with 4.93 dBm output power. It was fabricated on a SiGe HBT (NEC NESG20131M05) substrate.

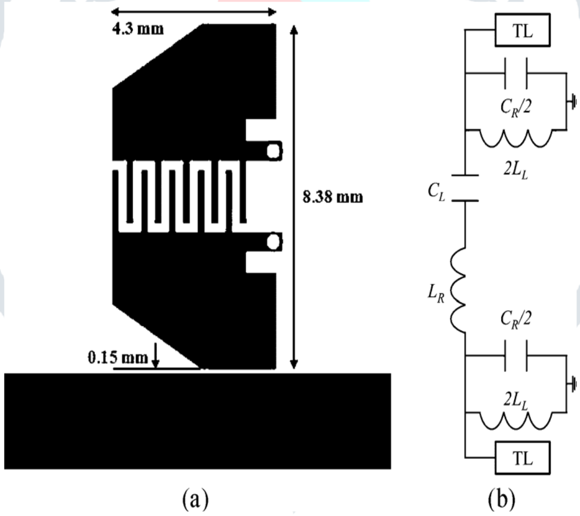


Fig 8. Proposed HSR (a) Layout (b) equivalent circuit

ANALYSIS & DESIGN OF HSR:

The proposed HSR consists of the CRLH TL -type unit cell and two CTLs as shown in Fig. 1(a), and it is coupled to 50 Ω.

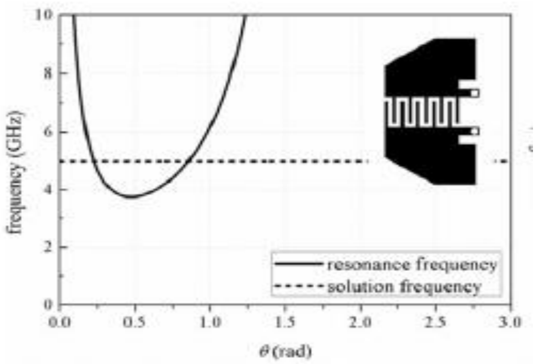


Fig 9. Resonance frequency vs. Θ

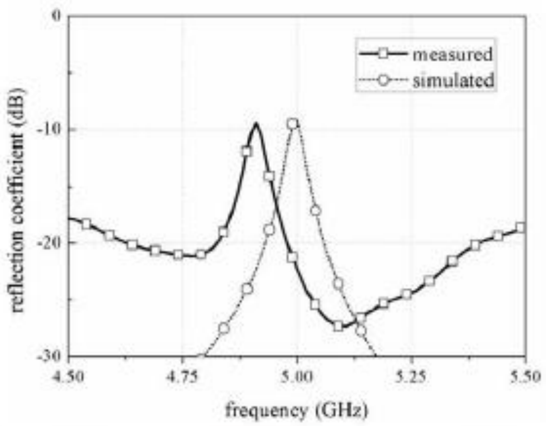
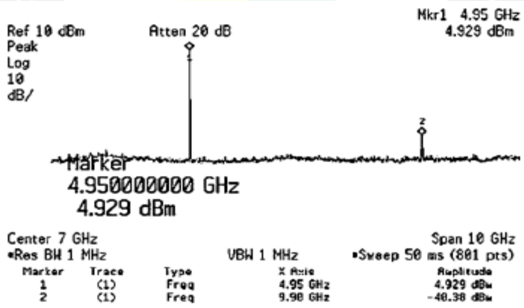
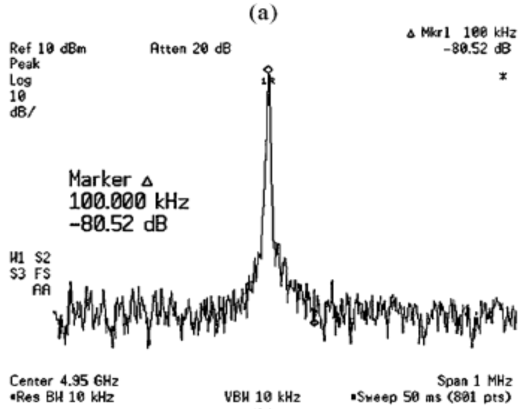


Fig 10. Measured & simulated reflection coefficient

There is some frequency shifting due to some fabrication errors within the tolerances. The loaded factors of the simulation and measurement are 125.6 and 114.2, respectively. Then, the loaded Q factor corresponds to the 3-dB bandwidth of S_{11} .Hence, a high- HSR is obtained with the compact size.



(a)



(b)

Fig 11. (a) Measured output spectrum

(b) Phase noise of fabricated oscillator

CONCLUSION

In conclusion, the various circuits involving the use of hairpin resonator as their unit cell have been observed and their results have been analyzed. The analysis is done by comparison between measured and simulated result of the circuits and by comparing various parameters such as phase insertion loss, return loss, substrate material etc. On observing various parameters, although tunable HSR based on LC has high oscillating frequency (mainly because of varying dielectric constant), Low Phase Noise Oscillator based on HSR using composite right/left-hand transmission line was having minimal phase insertion loss and minimal return loss; also it was very compact in design and was having a high-Q factor. In order to achieve a high-Q factor, the electric field was concentrated on CRLH TL in the HSR, and then it provides a slow wave effect, this oscillator can be fully integrated in the MMIC with low cost mainly because of its planar structure. Thus it was the best circuit based on Hairpin Shaped Resonator so far.

PARAMETERS	Tunable HSR based on LC	Cross Coupled Microstrip HSR	X Band Low Phase Noise Oscillator	Low Phase Noise Oscillator Using CRLH TL
Substrate Material	Alumina substrate	RT/Duroid substrate	Teflon substrate	SiGe HBT(NEC NESG20131M05) substrate
Dielectric Constant	varying	10.8	2.52	-
Phase Insertion Loss	-	3.8 dB	0.4 dB	minimal
Return Loss	-16 dB	-33 dB	-18 dB	minimal

REFERENCE:

[1] M.L. Lee and K.M. Lee "Multilayered Miniaturized Hairpin Resonator for Bandpass Filter Design", Progress in Electromagnetic Research Symposium Proceedings, KL, MALASIYA, March 27-30, 2012.

[2] Jia-Sheng and Michael J. Lancaster "Cross-Coupled Microstrip Hairpin-Resonator Filters", IEEE Transactions on Microwave Theory and Techniques, Vol. 46, No. 1, January 1998.

[3] Ki-Cheol Yoon, Hyunwook Lee, Jong-Chul Lee, Bhanu Shrestha, and Nam-Young Kim "Design of an X-Band Low Phase Noise Oscillator Using a Complementary Spiral Resonator", Proceedings of the Asia-Pacific Microwave Conference 2011.

[4] Byeong-Taek Moon and Noh-Hoon Myung "Design of Low Phase-Noise Oscillator Based on a Hairpin-Shaped Resonator Using a Composite Right/Left-Handed Transmission Line", IEEE Microwave and Wireless Components Letters, Vol. 24, No. 1, January 2014.

[5] Yingjie Di, Peter Gardner, Peter S. Hall, H. Ghafouri-Shiraz, and Jiafeng Zhou " Multipled-Coupled Microstrip Hairpin Resonator Filter", IEEE Microwave and Wireless Components Letters, Vol. 13. No. 12, December 2003.

[6] Haiwen Liu, Pin Wen, Xiaomei Wang,Yan Wang, Xuehui Guan, Xiang Xiao and Zhewang Ma "Dual Band High Temperature Superconducting Hairpin-Resonator Bandpass Filter Based on Two Pairs Of Non Degenerate Modes", IEEE Transactions on Applied Superconductivity.

[7] O. Yurduseven, A.E. Yilmaz and G. Turhan-Sayan "Hybrid-Shaped Single Loop Resonator: A four Band Metamatrial Structure", Electronics Letters Vol. 47 No. 25 8th December.

[8] A. Mirfatah and J.J. Laurin "Tunable Hairpin Resonator Based on Liquid Crystal", 13th International Symposium on Antenna Technology and Applied Electromagnetic and the Canadian Radio Science Meeting, 2009.