International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
Volume 3, Issue 12, December 2014

An Improved Design of Composite Right Left Hand Stepped Impedance Resonator Bandpass Filter for Wireless Communication Application

Richa Priyadarshani, Megha Agarwal, Pallavi Verma

Abstract— **In this paper, improved design of composite right left hand stepped impedance resonator based bandpass filter is presented. To design the filter, first an unbalanced composite right/left handed transmission line (CRLH-TL) unit cell using stepped impedance resonator (SIR) is designed and using this unit cell a CRLH SIR bandpass filter (BPF) is designed. To analyse the performance of the filter the simulated and measured results of filter are compared. The filter performs very well in terms of both insertion loss (-1.19 dB) and return loss (-27.83 dB) and gives a fractional bandwidth of 10.9%.**

Index Terms— **Composite Right Left Hand(CRLH), Left Handed Metamaterials(LHM), Stepped Impedance Resonator(SIR),Vector Network Analyzer(VNA).**

I. INTRODUCTION

"Left Handed Metamaterials (LHMs) are artificial structures that can be designed to exhibit specific electromagnetic properties not commonly found in nature." In the last few years, there has been an increased interest in the scientific community in the study of LHMs because of its exceptional properties such as a negative permittivity, negative permeability, negative refractive index and generation of backward waves, reversal of Snell's law, reversal of Doppler Effect, and the Vavilovcerenkov effect which are not readily found in nature. The history of LHMs started in 1967 with the visionary speculation on the existence of "substances with simultaneously negative values of permittivity and permeability" by the Russian physicist Victor Veselago [1]. LHMs based microwave circuits have many advantages such as: miniaturization in size [3-5], performance improvement of communication system [4]. Planar LH structures can be realized by using mainly two configurations: an array of split ring resonators and thin wires (resonating approach); and periodically loaded transmission lines (TL) often using series capacitance and shunt shorted inductance [1,6]. But resonant approach based metamaterials circuits are bulky, lossy and narrow band due to the requirements of operation near resonant frequency, hence in general not practical for microwave applications. So in this paper, transmission lines based MTMs circuits are being implemented.

Richa Priyadarshani,*ECE ,Amity University Delhi, India, 09718364295*
Megha Agarwal, *ECE ,Amity University.,Delhi, India, 09654582550*
Pallavi Verma, *EEE ,Amity University. Delhi, India, 09910348910*

It has also been known that SIR has been the most popularly used resonator for filter design amongst all configurations of planar transmission line resonators used for microwave applications [6-9]. This is because of its capability to reduce resonator (hence filter) size without degradation of the unloaded-Q as well as being able to control spurious frequencies hence stopband rejection [9].

In this paper, design of Stepped Impedance Resonator (SIR) Bandpass Filter, based on CRLH TL is presented. CRLH TL configuration is applied to Stepped Impedance Resonator (SIR) to form a structure which possesses unique characteristics of both SIRs and CRLH TLs. A novel bandpass filter (BPF) is then proposed by using CRLH SIR that can either provide enhanced performance or have significantly smaller size while maintaining the integrity of filter's performance.

In doing so, firstly SIR is designed and characterised based on CRLH TL. Pair of designed CRLH SIRs is coupled to design the CRLH SIR Bandpass filter. The filter design is first explained theoretically followed by electromagnetic full wave simulations, design investigation, fabrication, characteristic verification, result discussion and conclusion.

II. CONFIGURATION AND DESIGN OF CRLH SIR BANDPASS FILTER

A. Resonance Condition for λ/4 type CRLH SIR

SIR is a TEM or quasi-TEM mode resonator composed of more than two transmission lines with different characteristic impedance. Different types of SIRs based on structural variation are Strip line configuration of quarter wavelength type, half wavelength type, one wavelength type and transmission line structure.

In this paper, a λ/4 type short circuited CRLH SIR (Fig. 1) is implemented whose coupling properties are used to design CRLH SIR Bandpass filter (BPF).

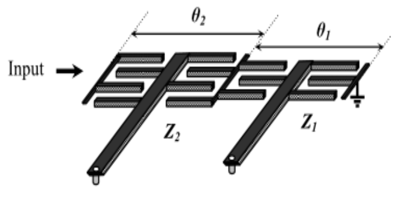

Figure1. Layout of λ/4 type short circuited CRLH SIR

ISSN: 2278 – 909X All Rights Reserved © 2014 IJARECE

When ignoring the influence of step discontinuity and edge capacitance at the open end, Z_i can be expressed as follows [7-9]

$$Z_i = jZ_2\frac{Z_1 tan\theta_1 + Z_2 tan\theta_2}{Z_2 - Z_1 tan\theta_1 tan\theta_2} \quad (1)$$

Let Y_i = 0, then the parallel resonance condition can be obtained as follows

$$Z_2 \; - Z_1 \; tan\theta_1 tan\theta_2 = 0$$

$$\text{Thus,} \quad tan\theta_1 tan\theta_2 = \frac{Z_2}{Z_1} = R_z. \quad (2)$$

Where, R_Z is impedance ratio

The overall electrical length is represented by [22]

$$\theta_{TA} = \theta_1 + \theta_2$$

$$= \theta_1 + tan^{-1}\left(\frac{R_z}{tan\theta_1}\right) \quad (3)$$

B. Design of λ/4 type CRLH SIR BPF

A CRLH SIR BPF has been designed at center frequency of 2.4GHz by using two pair of symmetrical λ/4 type short circuited CRLH SIR coupled lines. The CRLH TL unit cell (fig2) made of microstrip line with series interdigital capacitors and shunt stub inductors connected to the ground plane, has been used for physical realization of CRLH SIR (fig.1). Each CRLH SIR is made of two such CRLH TL unit cell sections of different impedances.

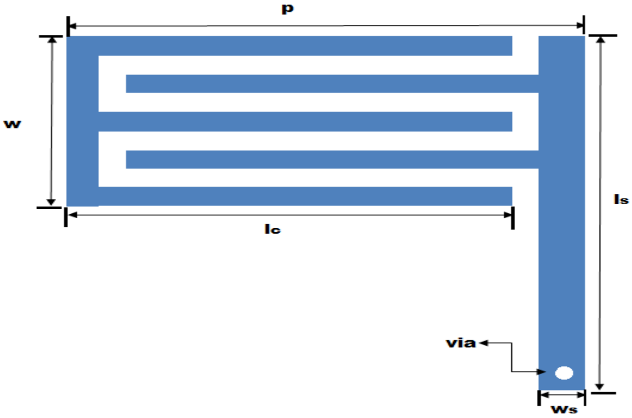

Fig2:Physical realization of 1-D CRLH unit – cell

In the Fig.2, ‘W’ is unit-cell width, ‘ l_c’ is the finger length, ‘P’ is the length of unit-cell, ‘l_s’ is the stub length and ‘W_s’ is the stub width. To design CRLH SIR, all these geometrical parameters are calculated at $f_o = 2.4GHz$ and for two different values of $Z_0 = 48\ \Omega$ and $42\ \Omega$ separately by following the design steps of microstrip transmission line [7,8]. The geometrical parameters of the BPF is given in table1.

Table 1: Design parameters for the CRLH SIR BPF

Variables	**Physical parameter of design(for Z_1= 48Ω)**	**Physical parameter of design(for Z_2= 42Ω)**
W (unit cell width)(2)	5 mm	4.68 mm
w_s (stub width)	1.35 mm	1.02 mm
l_s (stub length)	12 mm	9 mm
N_1 (No. of fingers)	3	2
w_c (interdigital finger width)	1.5 mm	2.09 mm
s (spacing between fingers)	0.32 mm	0.78 mm
l_c (interdigital finger length)	3.5 mm	2.9 mm
P (unit cell period)	11.4 mm	11.4 mm
h (substrate height)	1.524 mm	1.524 mm
ε_r (substrate permittivity)	2.55	2.55
g_1 (interstage spacing)	2.2 mm	3.5 mm

To design the CRLH SIR BPF, non uniform coupling of g1 and g2 is provided between CRLH SIR coupled lines and connected at a point where they are shorted by a metallic via as shown in fig.3. Each shunt stub inductor is shorted by via of radius 0.25 mm and inverter via is of radius 0.2 mm.

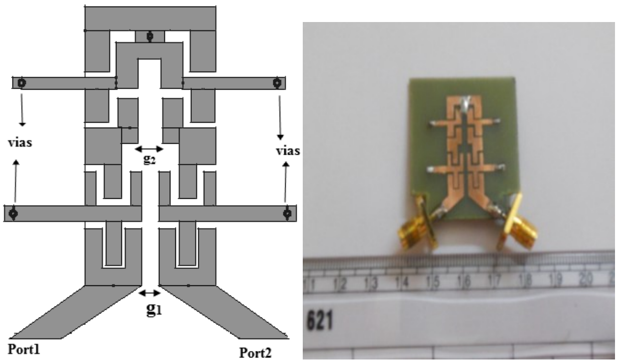

Fig. 3 Layout of the CRLH SIR BPF

III. RESULT

For investigation of frequency characteristics of CRLH SIR BPF, it has been simulated using commercially available full wave electromagnetic simulator IE3D, based on method of moment (MoM), using Arlon DK Substrate with Dielectric constant = 2.55, Loss tangent (tan D = 0.0009), and Thickness, h = 1.524 mm and it has been fabricated on the same substrate. The simulation result is shown in fig.4.

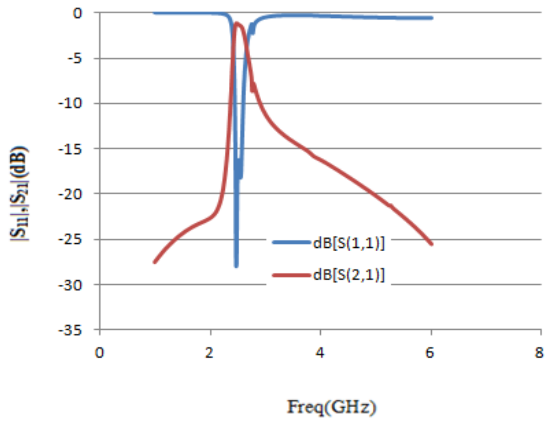

Fig. 4 Simulated S-parameter vs. frequency plot for designed CRLH SIR BPF

The fabricated structure is measured through VNA (Vector network analyzer) and a comparison between the experimental and simulated result is shown in Fig.5. It can be seen that the experimental result has good agreement with simulation result.

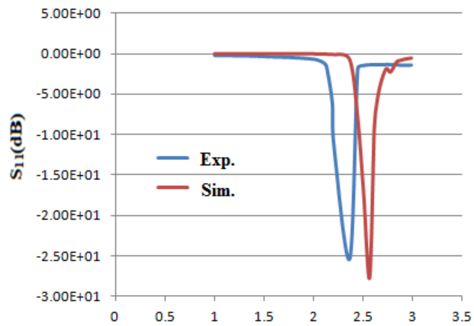

Fig. 5(a) Comparison between Sim. and Exp. result for $|S_{11}|$

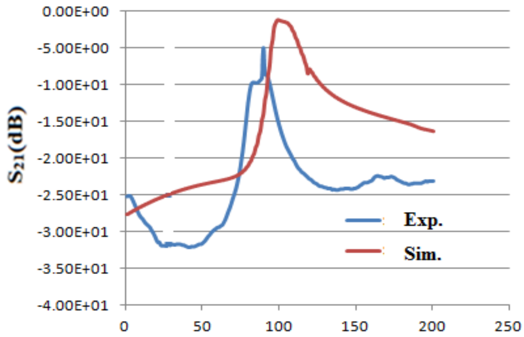

Fig.5(b) Comparison between Sim. and Exp. result for $|S_{21}|$

IV. CONCLUSION

Stepped Impedance Resonator (SIR) Bandpass Filter, based on CRLH TL is presented in this paper. It is clearly evident from the simulated result, that the designed filter is centered at 2.47GHz and performs very well in terms of both insertion loss (-1.19 dB) and return loss (-27.83 dB) and gives a fractional bandwidth of 10.9%.

This designed filter can be used for both Bluetooth application and WLAN application.

V. REFERENCES

[1] V. Veselago, “The electrodynamics of substances with simultaneously negative values of ε and μ,” Soviet Physics Uspekhi, vol. 10, no. 4, pp. 509–514, Jan., Feb. 1968.

[2] J. B. Pendry, "Negative refraction makes a perfect lens," Phys. Rev. Lett., vol. 85, pp. 3966—3969, Oct. 2000.

[3]C. Caloz, C. Chang, and T. Itoh, "Full-wave verification of the fundamental properties of left-handed materials in waveguide configurations," J. Appl. Phys., vol. 1, pp. 5483-5486, Dec. 2001.

[4] D. R. Smith, W. J. Padilla, D. C. Vier, S. C. Nemat-Nasser, and S. Schultz. “Com-posite medium with simultaneously negative permeability and permittivity,” Phys. Rev. Lett., vol. 84, no. 18, pp. 4184–4187, May 2000.

[5] C. Caloz, H. Okabe, T. Iwai, and T. Itoh, "Transmission line approach of left- handed (LH) materials," presented at Proc. USNC/URSI National Radio Science Meeting, San Antonio, TX, June 2002.

[6] S. Karimian and Z. Hu ,”Metamaterial Stepped Impedance Resonator Bandpass Filter Based on Composite Right/Left-Handed Transmission Lines ,” Proceedings of the 41st European Microwave Conference, 10-13 October 2011.

[7] D.M. Pozar, Microwave Engineering, 2nd ed. New York: Wiley,1998,ch.8.

[8] Reinhold Ludwig, Pavel Bretchko, “RF Circuit Design: Theory and Applications”, Prentice Hall 2000.

[9] M. Makimoto, S. Yamashita, “Microwave resoantors and filters for wireless communication,”springer, 2000.

ISSN: 2278 – 909X All Rights Reserved © 2014 IJARECE