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Ultra Wide Band Bandpass Filter using CR/LH Transmission Line and MMR

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***Abstract*— This paper presents two design of band pass filter using multi mode resonator. The first design includes a new Ultra Wide Band Bandpass Filter based upon microstrip CRLH transmission line to get proper results in an attempt to reduce the size which is most important aspect in micrstrip technology with special features of CRLH-TL. The interdigital capacitor with strong coupled lines is used here. The second design represents a microstrip band pass filter using MMR in order to full band transmission. Both designs will give good simulation results i.e. insertion loss, return loss, flat group delay response with appropriate fractional bandwidth.**

***Keywords*— Band pass filter, Multi mode resonator, Composite right/left handed –transmission line**

I. INTRODUCTION

In recent years generous studies have been conducted to bring into play the benefit of the UWB communication since its unlicensed used was open to public by the FCC to meet the required UWB frequency mask 3.1 to 10.6 GHz, It has been recognize that UWB bandpass filter with in-band transmission and out-off band rejection performance is highly demanded in wireless transmission systems. Compact micro strips-line UWB bandpass filter using stub- loaded multiple mode resonator (MMR) design by properly loading three open- ended stubs in shunt to a simple stepped- impedance resonator in center and two symmetrical locations presented in [2]. This filter provides insertion loss upto 0.8 dB, return loss higher than 14.3 dB and maximum group delay variation less than 0.64 ns.[1] presents a novel micro strip –line ultra –wideband bandpass filter using MMR aiming with transition of the signals within complete band this design is implemented to achieve the first three resonant mode frequency. Design includes the parallel coupled lines. This results the return loss is found better than 10dB, group delay variation is less than 0.23 ns .Complementary Split Ring resonator s using CRLH metamaterial transmission lines to obtain continuous transition between left handed and right handed bands presented in [3]. Purely resonant type and hybrid approach include with this concept. In hybrid approach microstrip line is loaded with complementary split ring resonator, series gap and ground stubs where purely resonant type is based on balanced line and loaded with complementary split ring resonator, series gaps. In order to reject undesired existing radio signals such as WLAN that may interfere with UWB passband the technique of embedding a parasitic coupled line to UWB BPF is presented in [5] which provide a narrow notch band. Three pair of defected ground structures are form to provide transmission zeros in out of band signals, H-shaped slot, tighten coupling of interdigital capacitor improves bandpass filter performance presented in [6]. Filter with conventional step impedance resonator and two coupled input-output lines forms UWB BPF with an embedded open circuited stub structure to improve in-band performance [7]. Concept of dual notch band using defected ground structures presented in [12] using two symmetrical dumb bell shaped interdigital capacitor obtain to notch band at 5.3 GHz and 7.8 GHz by developing a meander line slot. This technique achieve pass band from 2.8 GHz to 11.0 GHz, wide stopband bandwidth with 20dB attenuation upto 30.0 GHz. Multiple stub loaded uniform transmission line resonator stand for two asymmetrical stepped impedance stub at center and four uniform impedance stubs at symmetrical side location that's why Quintuple –Mode UWB bandpass filter is in [9] gives sharp roll off and 20 dB stopband performance is upto 29.7 GHz. Open stub's embedding in first and last connecting lines to reject undesired radio signals interrupt with passband having with five short circuited stub provides united design in [10].This concept is smartly work with High selectivity.[18] amin abbosh studied balanced Ultra Wide Band bandpass filter includes tapered patch and slot configuration help to reach to satisfactory results of Fractional bandwidth 123% with center frequency 6.55 GHz, upper and lower stop band , group delay with ultra wide band. [21] represents Three section broadside coupled bandpass filter within microstrip patches at top and bottom layer of structures gives suitable results with ultra wide band characteristics. A new 5 GHz notched band bandpass filter design using stepped impedance slotline multimode resonator to obtain differential mode response, concept of common mode rejection signal is introduce here in [19], common mode suppression is larger than 18.85 dB. [22] Presents compact ultra wideband bandpass filter having improved stopband with compact size implemented using MMR Insertion loss is higher than 30.0dB in upper stopband. Paper describes two different designs of UWB band pass filter with stepped impedance resonator. First design with study of selectivity and notch band is described here. Second design also includes stepped impedance resonator with full band coverage. Simulation results of first design unable to give satisfactory upper cut off.

A new UWB bandpass filter design using Composite Right/ Left Handed transmission Line is presented. Design structure includes a symmetric unit cell Composed of interdigital coupled lines with a short circuited stub which is inductive and provides higher passband selectivity, lower passband insertion loss across UWB region. The interdigital capacitor and short circuited inductive stub togetherly represents left handedness highpass nature of structure. The effective inductance of interdigital lines and effective capacitance of short circuited inductance represented right handedness lowpass nature of structure.

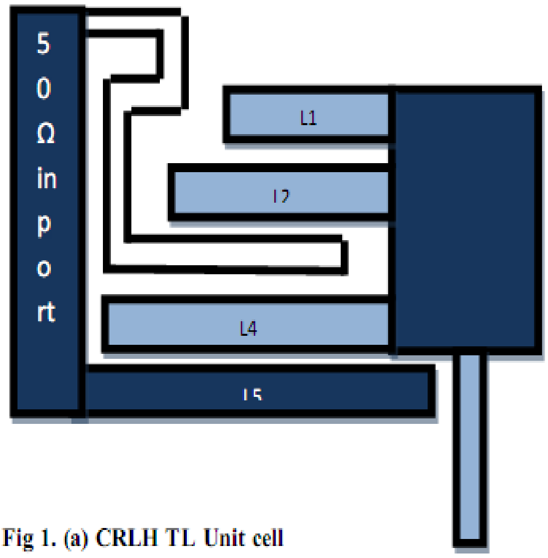


Fig 1. (a) CRLH TL Unit cell

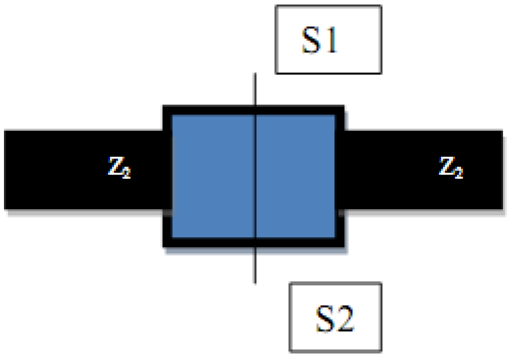


fig1(b) MMR

The effective inductance of interdigital lines and effective capacitance of short circuited inductance represented right handedness lowpass nature of structure. The middle section of structure represents Multi Mode Resonator provides bandwidth expansion and resonant frequencies. The modified unit cell is constituted by an interdigital capacitor ended with two transmission line section and short circuited stub is grounded through via. The goal of the transmission line cell is to reduce the effect of the parasitic resonance of interdigital capacitor on passband. The self resonance frequency of interdigital capacitor reduces as capacitance increases. So, first frequency may enter the passband at appropriate finger length of interdigital capacitor. Filter selectivity and notched band performance is improved by direct coupling of L-shaped structure stepped impedance attachment and L-shape attachment at right side respectively. The Ultra Wide Band bandpass Filter using CRLH TL reach to results that fractional bandwidth more than 80%, insertion loss is less than 1 dB, return loss is better than 10 dB. Simple, easy design, improved structure and most important aspect in microstrip technology is reduced size.

I. *FILTER DESIGN AND SYNTHESIS*

The Ultra Wide Band bandpass filter structure includes Composite right left handed transmission line. The interdigital capacitor and short circuited inductive stub represents left handedness highpass nature of structure. The effective inductance of interdigital lines and effective capacitance of short circuited inductance represented right handedness lowpass nature of structure. The length of coupling lines of interdigital capacitor i.e. fingure length is indicated in unit cell separately. When the change in length L3 occurs it affects on transmission Zeros frequency, L1 and L2 are design to get higher resonance mode and affect to filter's passband. The length L4 affect on filter's passband as length L4 get reduce and response shift to higher frequencies and lower cut off of filter passband is depend on length of short circuited inductive stub. The length of short circuited inductive stub is 2.8 mm. The middle section of structure represents Multi Mode Resonator provides bandwidth expansion and resonant frequencies.

The middle transmission line structures comprises of High- low- high i.e. stepped impedance section of MMR. The Characteristic impedance of middle low impedance section is denoted by Z1 and high impedance section is denoted by Z2. θ_1 and θ_2 are the electrical length of MMR respectively. In the analysis two case are taken in consideration when symmetry plane S1-S2 is short circuited and not Short Circuited

Case1: When Symmetry plane S1-S2 is not short circuited the input admittance Yi is given by

$$Yi = j\,Y2 \left\{ \frac{2\,(k\tan\theta 1 + \tan\theta 2)(k - \tan\theta 1 \tan\theta 2)}{k(1-\tan^2\theta 1)(1-\tan^2\theta 2) - 2(1+k^2)\tan\theta 1 \tan\theta 2} \right\} \qquad (1)$$

Case2: When Symmetry plane S1-S2 is short circuited the input admittance Yi is given by

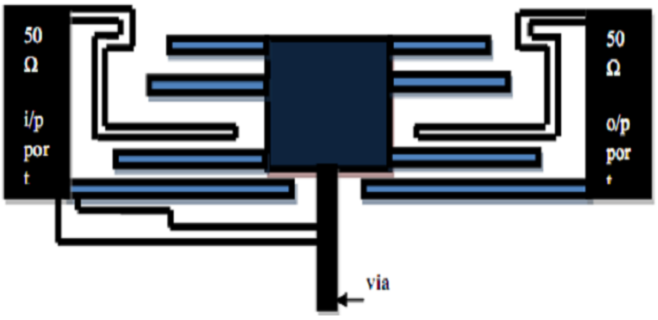
$$Yi = jY2 \left\{ \frac{(k - \tan\theta 2 \tan\theta 1)}{(\tan\theta 1 + k\tan\theta 2)} \right\}$$

Where k = Z2/Z1 (impedance ratio) (2)

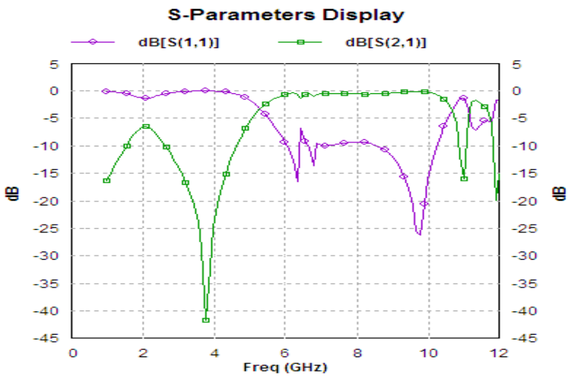
The structure includes interdigital capacitor with n number of finger. The length of each finger have specific importance in case of lower attenuation pole frequency, upper attenuation pole frequency, Lower and upper cut-off of passband, out of band characteristics. Short circuited stub length affect on lower cut of passband as length of stub decreases response shift to right side.

This new method of composite material helps to improve the selectivity of UWB filter. Which gives sharp cut-off to introduce transmission zeros. The Step impedance attachment between source feed line and short circuited inductive stub help to improve selectivity of filter. The coupling gaps are determined to avoid attenuation poles at unwanted frequency within passband. The length of step impedance attachment is 8.3 mm. The filter is design and simulated in microstrip technology using IE3D Zeland software which help to obtain very sharp and remarkable results. The relative permittivity Єr = 2.17, h = 0.891 mm. Filter reach to good results in insertion loss is less than 1 dB as well as return loss is better than 10 dB and flat group delay response.

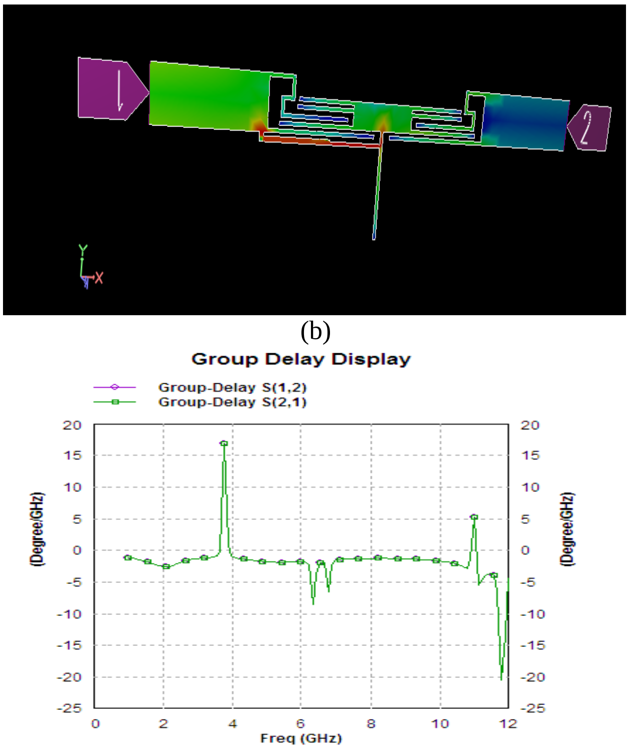
Fig 2 shows complete structure of Ultra Wideband Bandpass Filter encapsulates interdigital capacitor, short circuited stub, feed lines, step impedance attachment, coupling lines to obtain good results of UWB Filter. Fig 3 (a), (b), (c) represents graph of passband insertion loss, return loss and group delay, current distribution file.



The symmetrical structure of Composite Right Left Handed Transmission Line cell with coupling arms of interdigital capacitor indicates LC tank circuit. The length of coupling arm L1=3.9mm, L2 = 4 .1mm, L 3 = 8.4 mm, L4 = 5.2 mm, L5 = 7.2 mm. The coupling gaps of width 0.2mm collectively provides tighten coupling. MMR with two separate scenarios when middle plane S1-S2 is short circuited and another is not short circuited is explained. When Symmetry plane is short circuited. $Y_i = 0$ resonant frequency can be obtained by $\theta_1 = \theta_2$ and $\theta_1 = 2\theta_2$. Same formulation can be done in case of second scenario of MMR and resonant frequencies can be obtained.



(a)



(b)

(c)

Fig 3 (a) S parameter display (b) Current distribution (c) Group Delay

A. *UWB notch band*

To observe notch band at 5.6 GHz fig 4 gives a new design structure of UWB band pass filter. L shaped attachment is attached here so that notch band can be observe. As length of attachment changes notch frequency shifts the notch band. Fig 5 gives simulation results of scattering parameter with length L=4.2mm, L=3.2mm, l=2.7 mm and group delay characteristics.

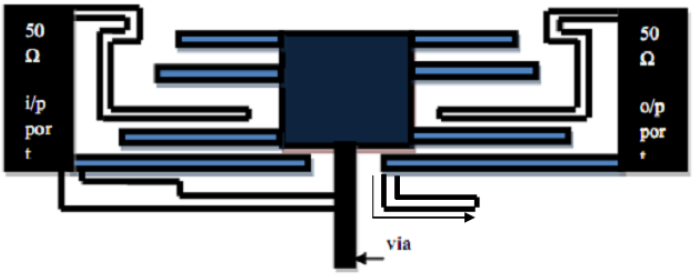
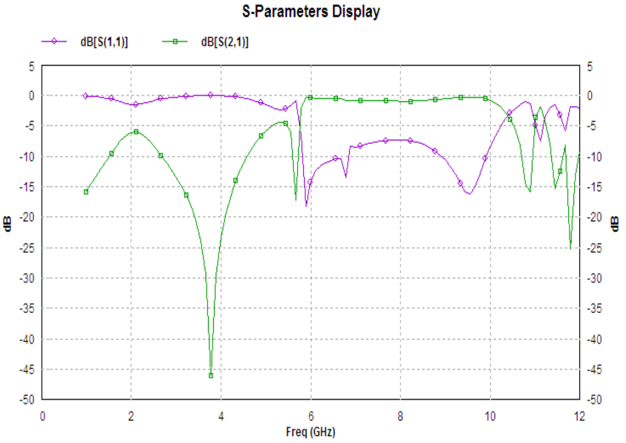
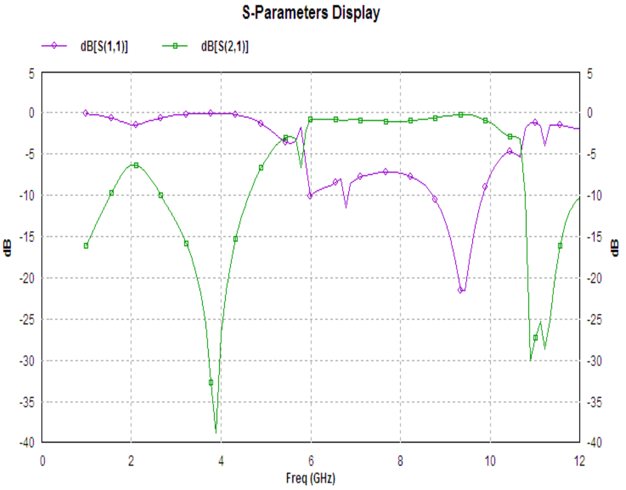


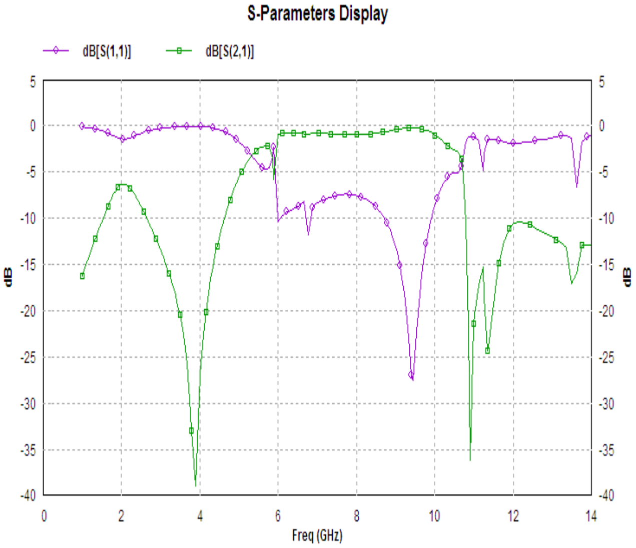
Fig 4. UWB Band pass filter design of notch frequency.



(a)



(B)



(c)

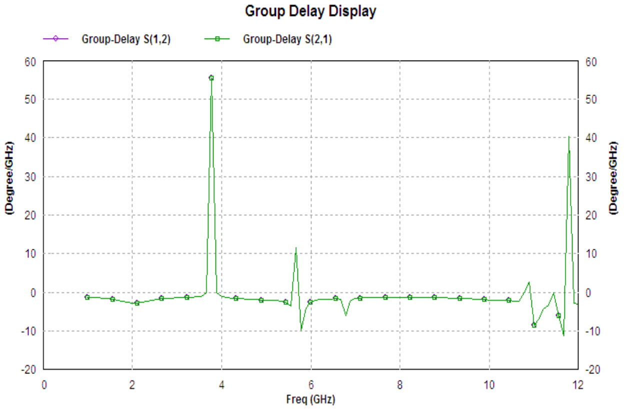
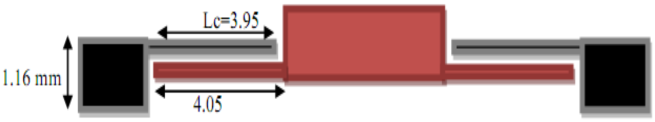


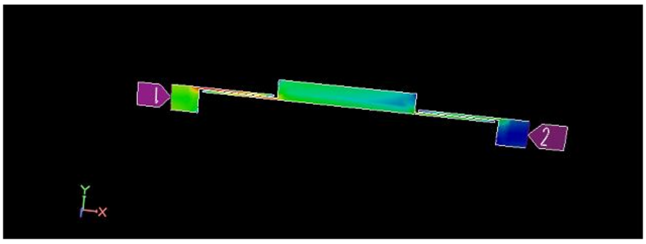
Fig5 (a) s-parameter display of notch band design L=4.2mm (b)L=3.2mm (c)L=2.7mm(d) group delay

II. NEW DESIGN OF UWB FILTER

Fig 6 shows ultra wide band filter using multi mode resonator. Stepped impedance resonator with high –low-high impedance section can be observe by the microstrip design. Design is simulated with different length of coupling lines as Lc=4.2 mm, Lc=3.2mm, Lc=2.7mm. Corresponding lengths gives insertion loss and return loss parameter description.

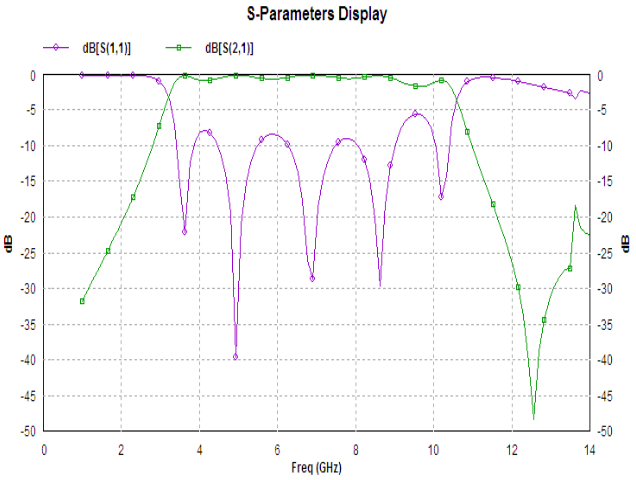


(a)

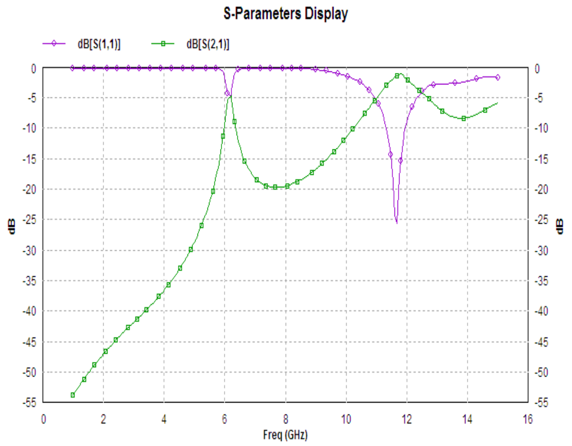


(b)

Fig 6.(a) Microstrip design of Band pass filter using MMR (b) current distribution file



(a)



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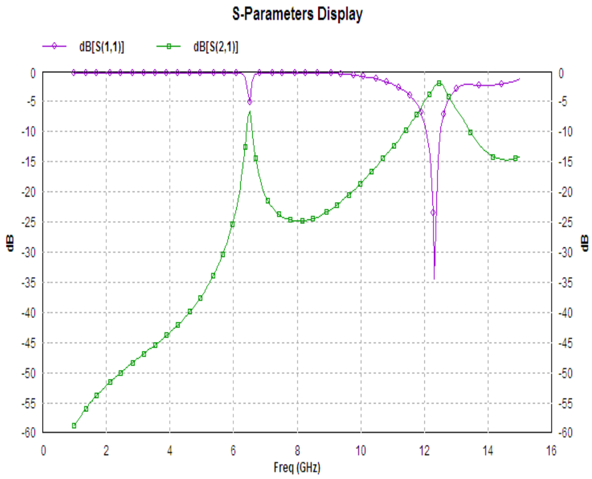
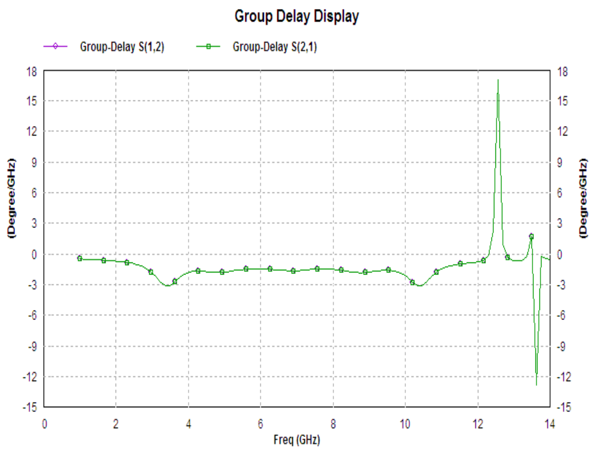


(c)



(d)

Fig 7s-parameters (a)Lc=3.95mm (b) Lc=0.50mm (c) Lc=0.10mm(d)group delay

Table 1. Comparison of both designs

Design no	**Єr(mm)**	**Size(mm^2)**	**S_{21} dB**	**S_{11} dB**	**FBW (%)**	**Group Delay(ns)**
1st	2.17	15.7 ×2.7	<1	10	80	0 to -10 deg/GHz
2nd	10.8	9.28 × 1.8	<1	10	110	0 to-3 deg/GHz

Table 1 gives comparison of both designed filter. First designed filter have 80% FBW, insertion loss less than 1 dB, return loss better than 10 dB, with reduced size, second design with 80% FBW, insertion loss less than 1 dB, return loss better than 10 dB, with reduced size. The comparison of two designs also included here in table. Both designs with reduced dimensions, good insertion and return loss performance, group delay response followed by simulation result. First design covers band 5.2GHz-10.6GHz and second design covers band 3.2GHz-10.5GHz at Lc =3.95mm. Maximum UWB band coverage is observed by second design.

IV. CONCLUSION

New types of design are implemented in this paper which takes benefit of characteristic of Composite Right Left Handed Transmission Line and multi mode resonator. By introducing the transmission lines, the parasitic self resonance of interdigital capacitor can be shifted to high frequencies and help to cover Ultra Wideband Spectrum. Designed filter with graceful results insertion loss is less than 1dB, return loss is better than 10 dB, good fractional bandwidth. A flat group delay response is observed by both designs. Filters are compact in size, easy to implement with good passband performance having size of 15.7 × 2.7 mm2 and 9.28 × 1.8 mm2 respectively.

V. FUTURE WORK

This design of UWB band pass filter has to work in future with improvement of upper cut off frequency, more size reduction.

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