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Design of Microstrip UWB bandpass Filter using Multiple Mode Resonator

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ABSTRACT : *In this letter, we present a design of microstrip ultrawideband (UWB) bandpass filter (BPF) for the use in UWB wireless communication application set by Federal Communications Commission (FCC). The UWB filter is realized with a Basic MMR (Multiple Mode Resonators) structure feed by interdigital coupled lines for achieving higher degree of coupling. The structure is optimized for high selectivity, inband and stopband performance. Finally for fabrication of this structure Rogers RT5880 substrate of thickness 0.4mm with Dielectric constant 2.2 is used. The electromagnetic simulation software, Computer Simulation Technology Microwave Studio (CST MWS) is used for the simulation and analysis of the designed structure. The comparison between simulated and fabricated measured result shows good agreement. The insertion loss of proposed filter is greater then 0.2 dB at 6.8 GHz and very flat over whole pass band also returns loss is less then -12db.*

Keywords - *Interdigital coupled lines, Microstrip, MMR, UWB*

I. INTRODUCTION

Ultra wideband (3.1–10.6 GHz) radio technology has tremendous progress now a days, and found potential application in medical imaging systems, pulse communication and ground penetration radar. One of the key components in the ultrawideband (UWB) communication system is the band pass filter (BPF) [1-2]. In recent years various UWB bandpass filters are reported based on numerous design techniques[3-13]. These are mainly ring resonator structure; hybrid microstrip/coplanar-waveguide (CPW) structure; multiple mode resonator structure. To achieve low cost and easy integration, these filters are usually implemented in a microstrip or coplanar waveguide technology.

We have to fulfill few requirements for designing a full band ultra wideband bandpass filter which are as:

- ✓ Ultra bandwidth like from 3.1 GHz to 10.6 GHz.
- ✓ Low insertion loss up to -1db.
- ✓ Low and flat group delay.
- ✓ Out-band performance (strongly required to meet the regulation such as the FCC's spectrum mask) [14].

In this paper, The MMR(Multiple Mode Resonator) structure is used to achieve a wide bandwidth. The position of first three resonant modes are optimized to locate in the UWB passband at the equal distance, and the fourth resonant mode is placed much above the upper stopband to achieve wide upperstopband. The MMR is feed by interdigital coupled lines gives higher degree of coupling and hence improve selectivity of the filter. The layout of proposed filter is shown in Fig.1 and its dimensions are presented in TABLE I.

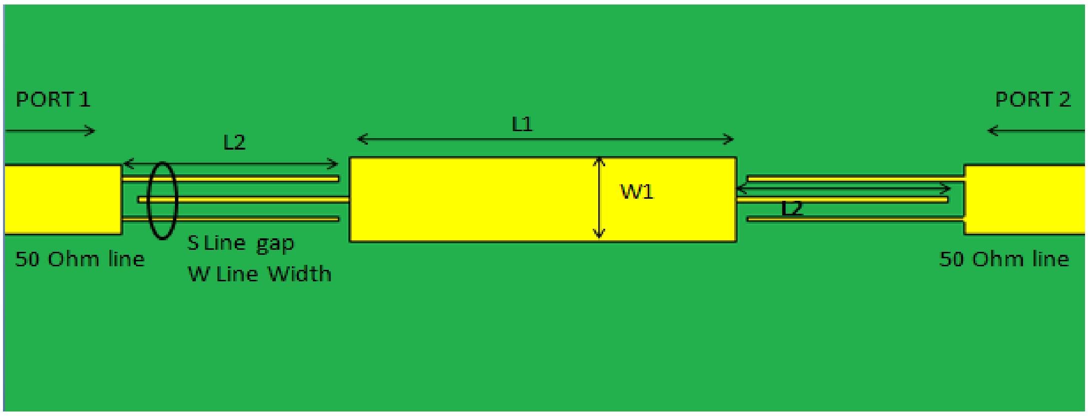


Fig 1. Layout of the proposed UWB bandpass filter

TABLE I. DIMENSION OF OPTIMIZED PROPOSED FILTER

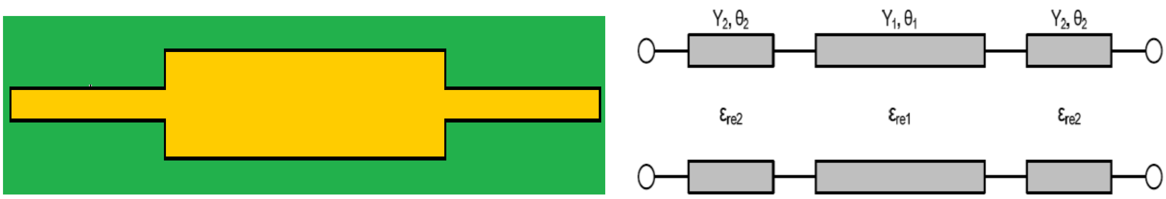
Filter parameter	**Value**	**Filter parameter**	**Value**
L_1	7.5mm	W_1	1.6mm
L_2	4.2mm	W	0.1mm
S	1.2mm		

In the next section we will discuss the simulated design and optimization of UWB band pass filter. The different resonant modes of MMR and locating these modes for our objectives are discussed in this section. The comparison of simulated and fabricated measured result is discussed in third section. Fabricated result shows quite similarity with the result simulated on EM simulation software. At the end we conclude the optimized design and its application.

II. FILTER DESIGN

Fig.1presents the geometry of the proposed UWB bandpass filter on Microstripline which consists of an open ended multiple mode resonator (MMR) and interdigital coupled lines. This MMR has one low-impedance section in middle and two high impedance sections in two sides. The high impedance sections are edge-coupled with the interdigital geometry to the I/P signal line. To get a UWB passband, the first three resonant modes are allocated near the lower-end, center, and high-end of the targeted UWB frequencies, and the quarter-wave interdigital coupled line excite two additional poles below and above the UWB's center or 6.85GHz.

Fig 2(a) depicts the open-ended Microstrip stepped impedance MMR. It is composed of three distinctive sections, one low-impedance section in the middle and two identical high-impedance sections insides. Fig 2(b) is its equivalent transmission line network model. This Microstrip MMR aims to make effective use of its lowest multiple resonant modes for wideband filter design. This MMR resonator is very similar to SIR in geometry and equilvalent topology, but it should be emphasized here that the so-called SIR only uses the lowest or dominant resonant mode in the design of narrow band filters with widened upper stopband.



(a) (b)

Fig 2. (a) Geometry and (b) equivalent circuit network of the multiplemode resonator (MMR).

The input admittance (Yin) at the left open-end, looking into the right side, as indicated in Fig 2(b).

$$Y_{in} = jY_2 \times \frac{2(K\tan\theta_1 + \tan\theta_2)(K - \tan\theta_1 \tan\theta_2)}{K(1-\tan^2\theta_1)(1-\tan^2\theta_2) - 2(1+K^2)\tan\theta_1 \tan\theta_2} \quad (1)$$

Where $K=Y_1/Y_2$ is the admittance ratio of two dissimilar sections in this MMR. At the resonance, $Y_{in}=0$ is valid. From Eq. 1, a set of algebraic equations are established to solve all the resonant to solve all the resonant frequencies, including the three lowest ones of interest, i.e. f_1, f_2, and f_3. In this design, electrical lengths of these two sections are selected as $\theta_1 \approx \theta_2 = \theta$ such that the three separate closed-form equations are deduced to individually determine f_1, f_2, and f_3. Eq. (2) and (4) presents the lower and higher frequencies, *f1* and *f3*, are mainly controlled by K, while the center *f2* relies on the selected actual lengths of the three sections in this MMR.

$$\theta(f_1) = \tan^{-1}\sqrt{K} \quad (2)$$

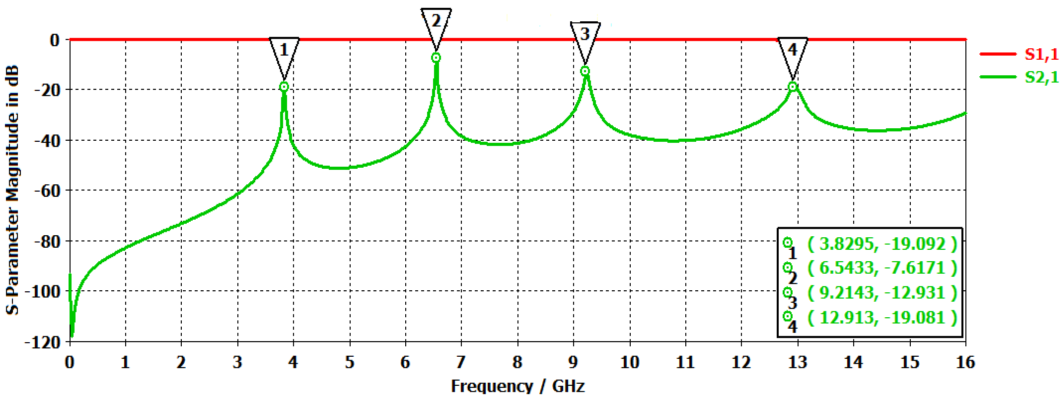
$$\theta(f_2) = \frac{\pi}{2} \quad (3)$$

$$\theta(f_3) = \pi - \tan^{-1}\sqrt{K} \quad (4)$$

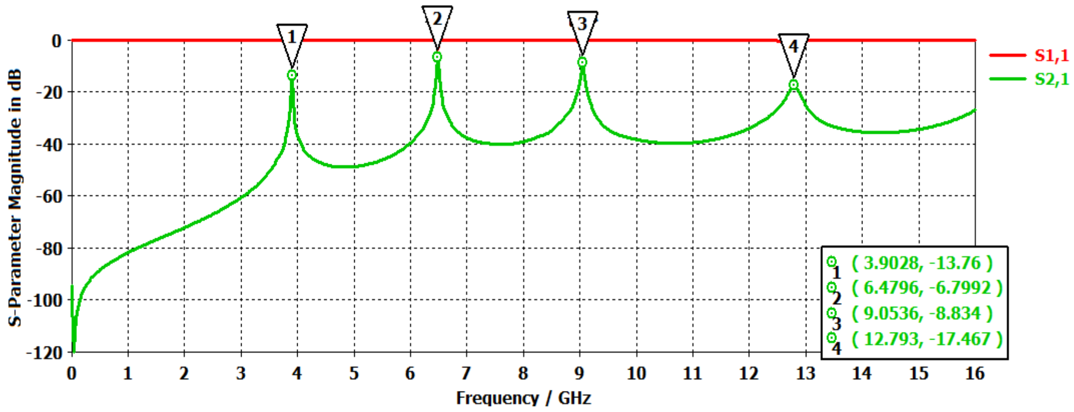
By de-tuning, the resonant frequencies can be observed and three resonant frequencies can be observed within UWB band. In the MMR the impedance ratio $K=Y_1/Y_2$ of low impedance line to high impedance line plays an important role for locating the resonant frequencies f_1, f_2, and f_3. The variation of resonant modes with varying impedance ratio K is presented in TABLE II. It is clear from the presented data that when we decrease the impedance ratio from 3.32 to 1.80, the resonant mode f_1 shifted from 4.3GHz to 3.8GHz and f_3 shifted from 8.5 GHz to 9.2 GHz, which shows that the distance of f_1 and f_2 from center resonant mode f_2 gets increased. The resonant mode f_4 is placed much above the upper stopband to achieve wide upper stopband. The S_{21}[dB] response under weak coupling of MMR with different impedence ratio K is shown in Fig. 3. Comparision of simulated detuned resonant frequencies with variation in impedance ratio is shown in Fig. 4.

TABLE II. VARIATION OF RESONANT MODES WITH IMPEDANCE RATIO K

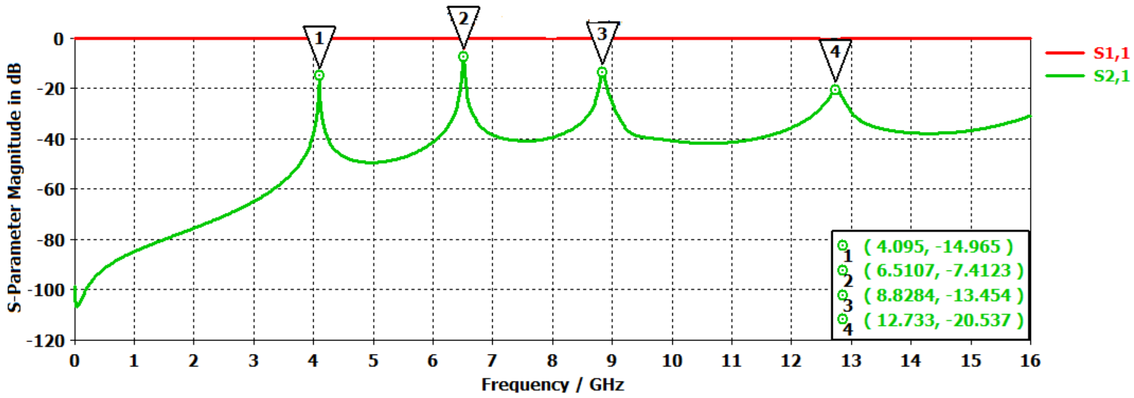
Impedance Ratio(K)	Resonant Frequencies(GHz)			
	f_1	f_2	f_3	f_4
3.32	**4.3GHz**	**6.4GHz**	**8.5GHz**	**12.5GHz**
3	4.2GHz	6.4GHz	8.6GHz	12.6GHz
2.7	4.1GHz	6.4GHz	8.7GHz	12.7GHz
2.4	4.0GHz	6.45GHz	8.8GHz	12.7GHz
2.1	3.9GHz	6.45GHz	9GHz	12.77GHz
1.80	3.8GHz	6.5GHz	9.2GHz	12.9GHz



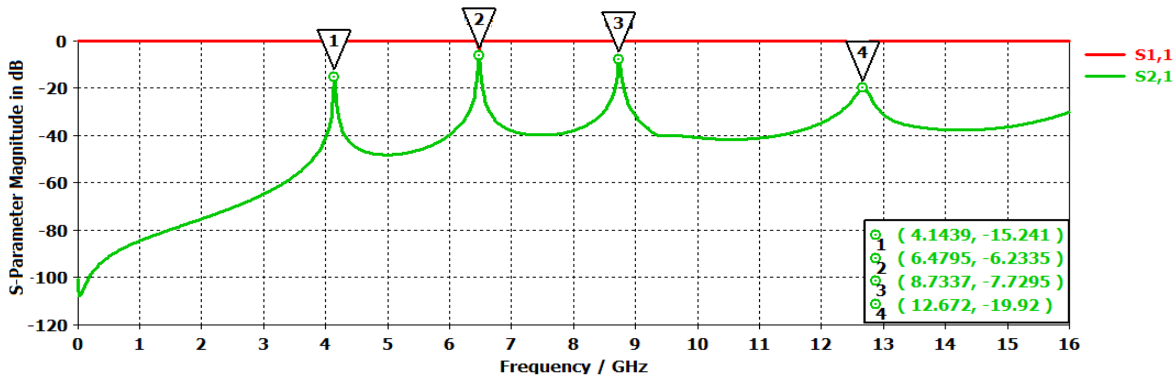
(a)


S-Parameter Magnitude in dB
Frequency / GHz
S1,1
S2,1
(3.9028, -13.76)
(6.4796, -6.7992)
(9.0536, -8.834)
(12.793, -17.467)

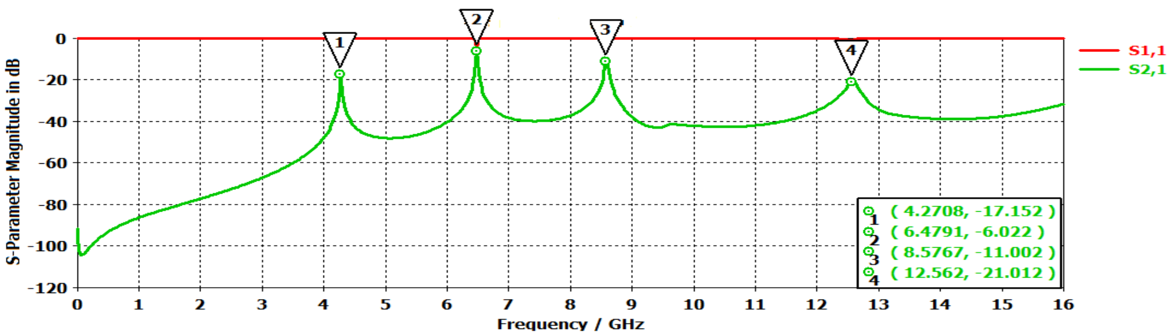
(b)


S-Parameter Magnitude in dB
Frequency / GHz
S1,1
S2,1
(4.095, -14.965)
(6.5107, -7.4123)
(8.8284, -13.454)
(12.733, -20.537)

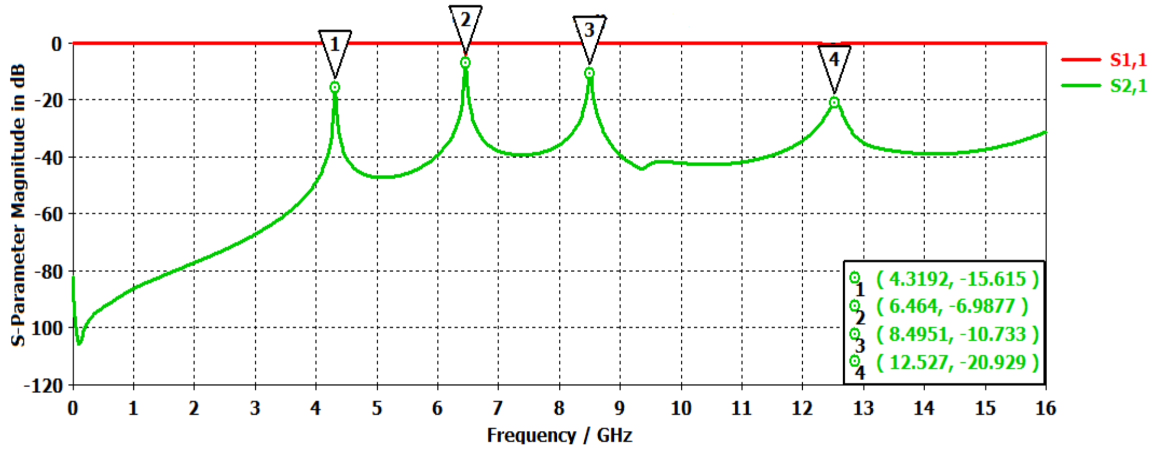
(c)


S-Parameter Magnitude in dB
Frequency / GHz
S1,1
S2,1
(4.1439, -15.241)
(6.4795, -6.2335)
(8.7337, -7.7295)
(12.672, -19.92)

(d)


S-Parameter Magnitude in dB
Frequency / GHz
S1,1
S2,1
(4.2708, -17.152)
(6.4791, -6.022)
(8.5767, -11.002)
(12.562, -21.012)

(e)



(f)

Fig. 3 Simulated detuned resonant frequencies with impedance ratio (a) K=1.80 (b) K=2.1 (c) K=2.4 (d) K=2.7 (e) K=3 (f) K=3.32

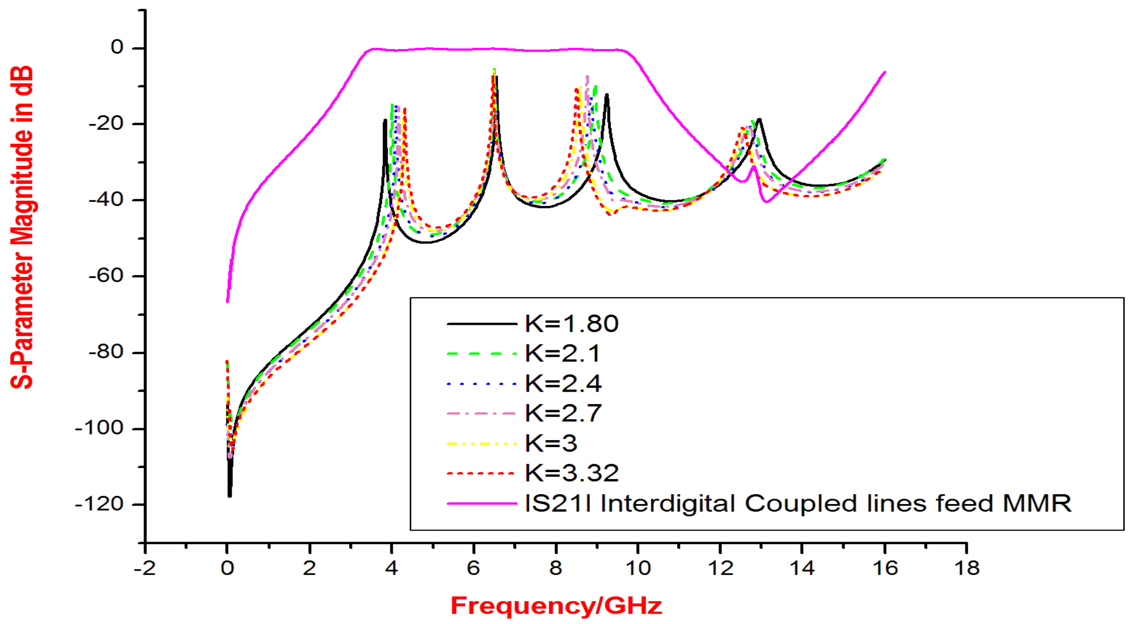
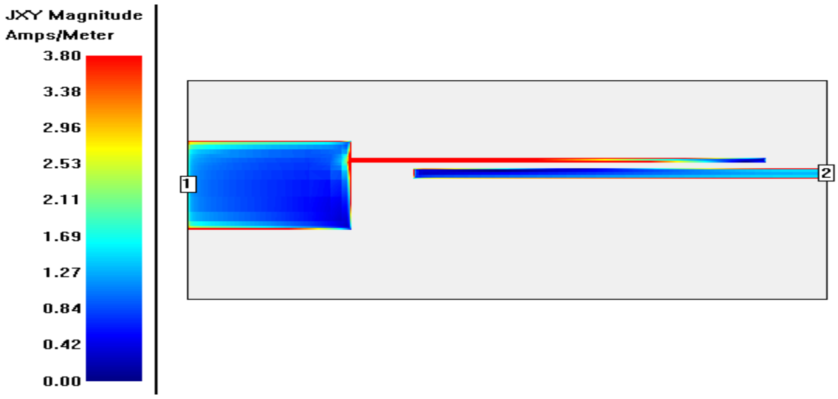


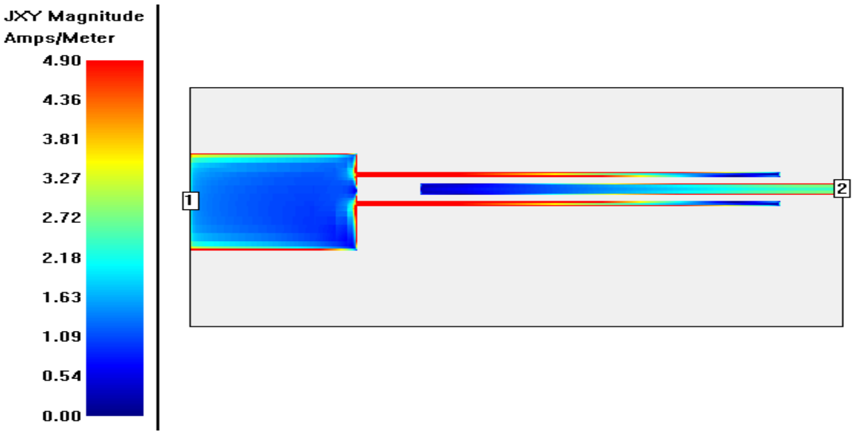
Fig. 4 Comparision of simulated detuned resonant frequencies with variation in impedance ratio (a) K=1.80 (b) K=2.1 (c) K=2.4 (d) K=2.7 (e) K=3 (f) K=3.32 and S_{21}[dB] of tuned MMR feed by interdigital coupled lines

Impedance ratio greater than 1 is utilised to design UWB filters. At the central frequency of the UWB passband, i.e., 6.85 GHz, the MMR structure is consist of one half wavelength λ/2 low-impedance line section in the center and two identical λ/4 high-impedance line sections at the two sides. So the MMR structure is optimized to cover all UWB passband such that the low impedance section is 51.65 Ω and high impedance section of the MMR is 140.93 Ω resulting in an impedance ratio of 2.72.

In this design we use Interdigital coupled lines as a I/O feed lines instead of single parallel line coupling. When giving energy to the MMR coupling energy of interdigital coupling is high compared with the single line parallel coupling. The current density result is shown in Fig. 3.4. The maximum current density of single line is 3.80 Amps/Meter and of double line it is 4.80 Amps/meter.



(a)



(b)

Fig. 5 (a) Current density distribution under single parallel line coupling. (b)Current density distribution under interdigital coupling.

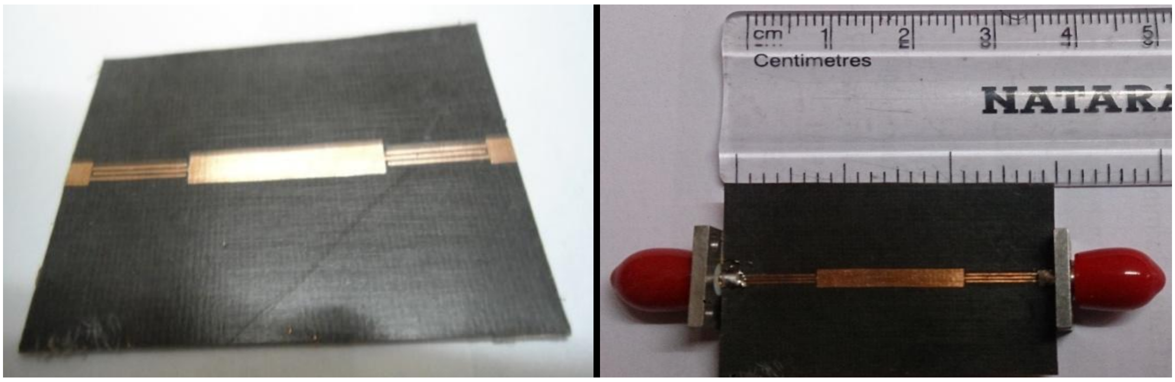
III. SIMULATED AND MEASURED RESULTS OF PROPOSED FILTER

Here the simulated and fabricated measured result of proposed ultra wide band bandpass filter structure is presented. The proposed filter is simulated by the help of the Electromagnetic (EM) simulation software. The return loss S11, insertion loss S21and group delay is discussed in this section.

Based on the design analysis presented above, the UWB BPF is realized by applying strong interdigital coupled feed lines to the presented MMR as shown in Fig. 1. The substrate used in this paper is *Rogers RT5880* with a relative dielectric constant of 2.2 and a thickness of 0.4 mm. Fig. 6 shows the photograph of the fabricated UWB BPF. The simulated and measured results are presented in TABLE III.

TABLE III. Simulated and Measured Results of Proposed UWB BPF

Parameter	**Simulated**	**Measured**
Center frequency (GHz)	6.85 GHz	6.8 GHz
Return loss S_{11}, S_{22} (dB)	Better than -12.3 dB in passband	Better than -13 dB in passband
Insertion loss S_{21}, S_{12} (dB)	About 0.2dB in the whole passband	About 0.4 dB in whole passband
Group delay	Less than 0.55 ns Linear in whole passband	Less than 0.57ns Linear in whole pass band



(a) **(b)**

Fig. 6. Photograph of the fabricated UWB filter

The simulated and measured results of the proposed UWB BPF are presented in Fig. 7 and Fig. 8 respectively. The comparison of simulated and measured result is presented in Fig. 9, good agreement between simulated and measured results is observed. As seen in Fig. 7, the 3 dB passband covers the range of 3.3–10.6GHz and it has a fractional bandwidth of 107%. The measured return loss is better than 12 dB within the UWB passband, and owing to the two transmission zeros in the lower and upper cut-off frequencies, sharp selectivity is observed. The measured upper stopband with 20 dB attenuation level is extended to 16 GHz. There are slight discrepancy may be due to the unexpected tolerance of fabrication and implement. In addition, the group delay within the UWB passband is between 0.56–0.85 ns, showing a good linearity as shown in Fig 9.

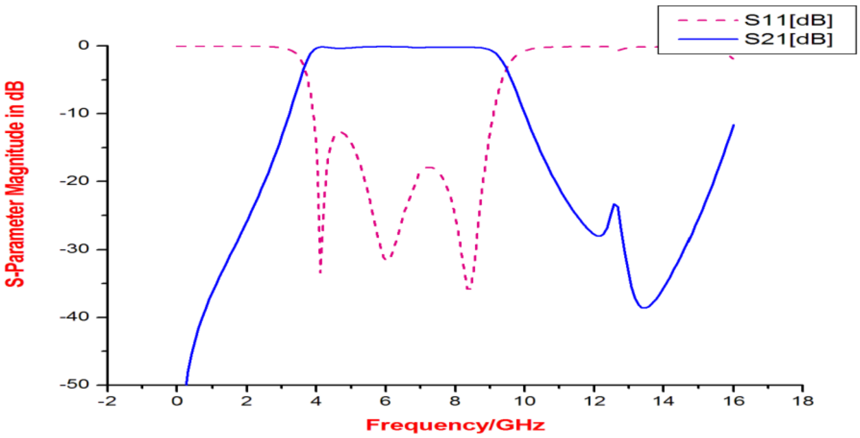


Fig. 7 Simulated result of proposed UWB BPF

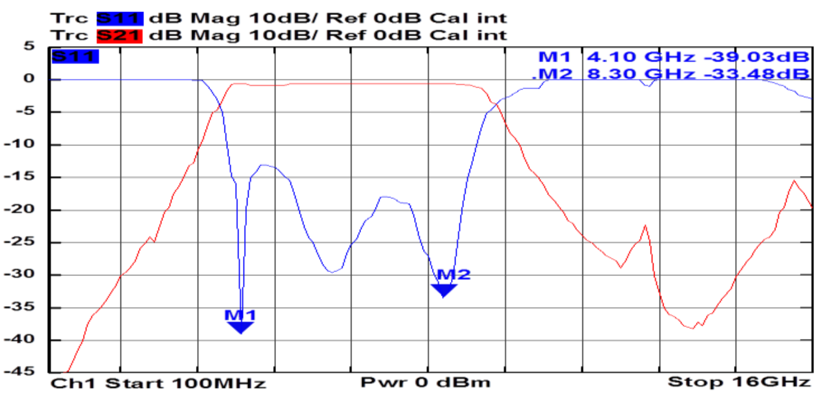


Fig. 8 Fabricated measured result of proposed UWB BPF

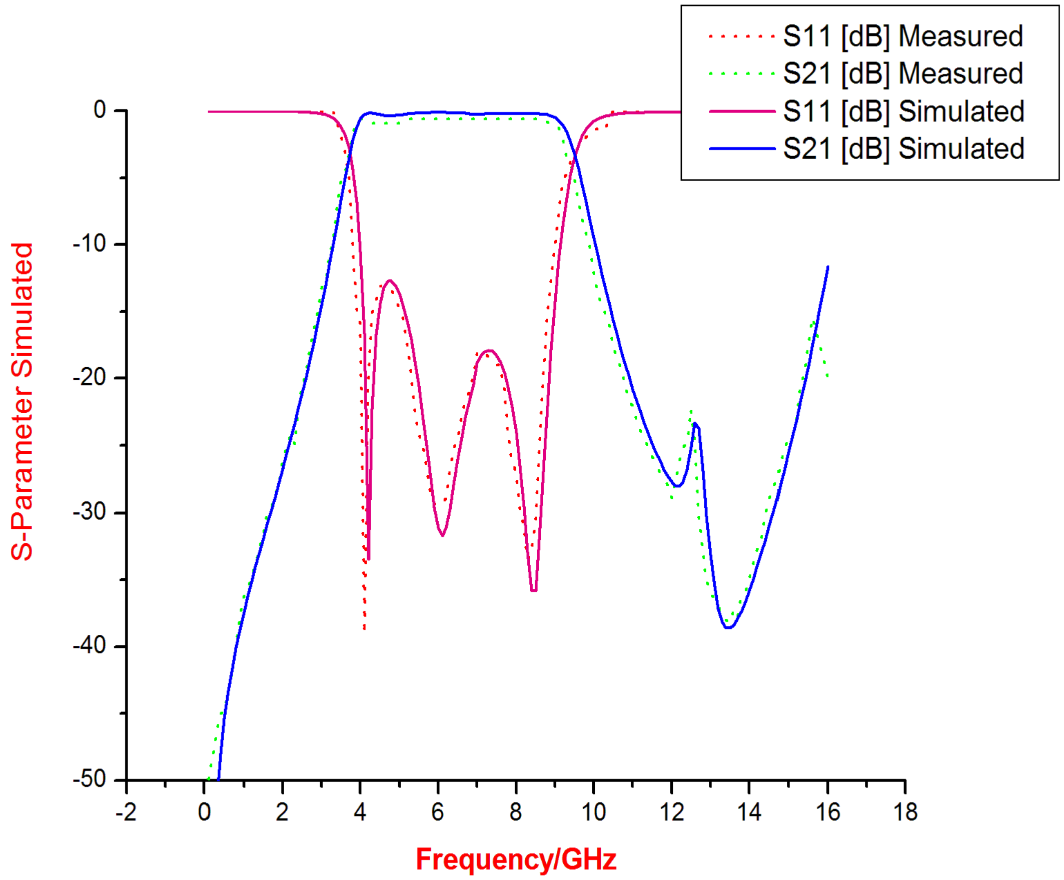


Fig. 9 Comparison of fabricated measured and simulated Result of proposed UWB BPF.

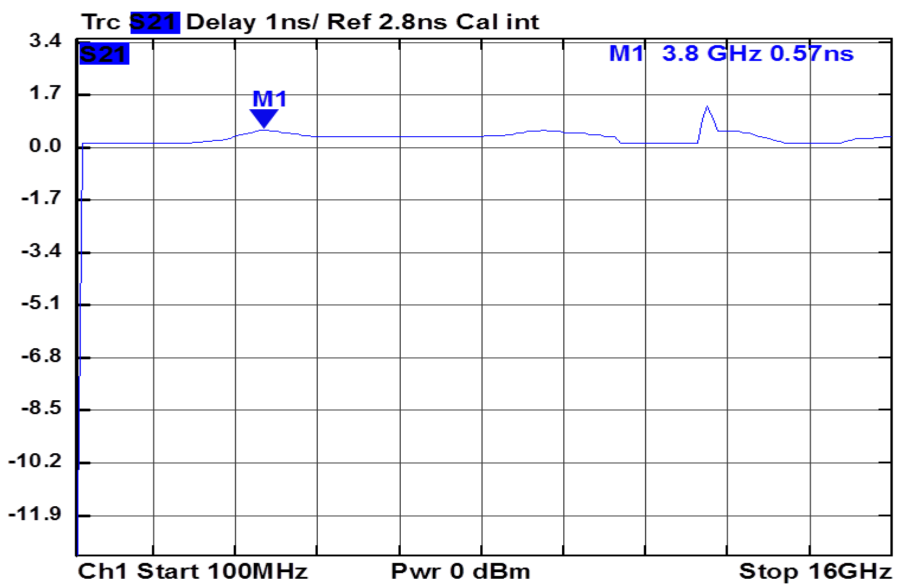


Fig. 10 Fabricated measured group delay result of proposed UWB BPF.

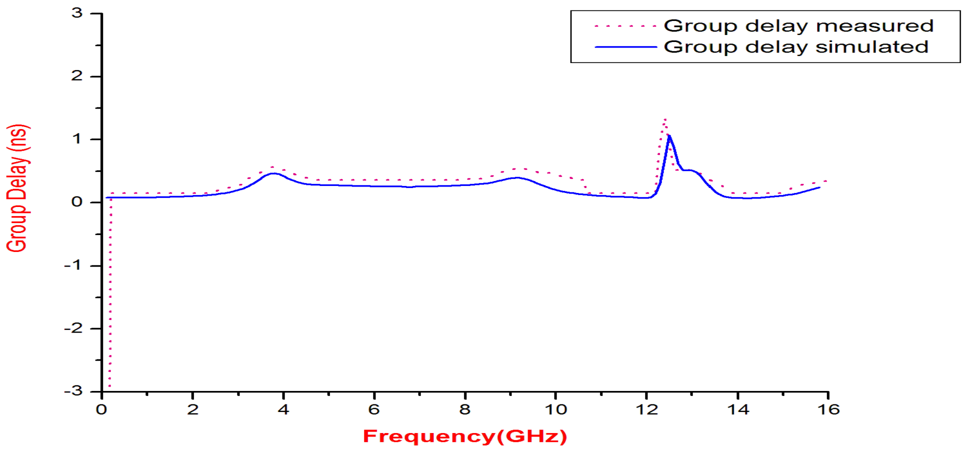


Fig. 11 Comparison of group delay result of proposed UWB BPF.

IV. CONCLUSION

In this letter, a compact UWB bandpass filter using MMR (multiple mode resonator) is discussed. As UWB filter is a part of UWB communication systems so it is always desirable to reduce the size of components. The MMR is constructed by one low-impedance section in middle and two high impedance sections in two sides. There are first three resonant modes of MMR are located in the UWB passband and fourth mode is placed much above the passband. The high impedance sections are edge-coupled with the interdigital geometry to the I/P signal line. By using MMR structure with I/O feed by double side coupled interdigital lines we can design compact filters even for wider bands. As earlier for increasing bandwidth and sharpness of a filter we have to increase the order of filter but that would make our filter bulky. MMR structure based designs give a perfect solution for this problem. The overall performance and Characteristic of designed filter is excellent and can be useful for any modern wireless device.

REFERENCES

[1] Qi Li, Chang-Hong Liang, *Senior Member IEEE*, Hai-Bin Wen, Guo-Chun Wu "Compact Planar Ultra-Wideband (UWB) Bandpass Filter with Notched Band" IEEE 2009.

[2] Sheng Sun, Student Member, IEEE, and Lei Zhu, Senior Member, IEEE "Capacitive-Ended Interdigital Coupled Lines for UWB Bandpass Filters With Improved Out-of-Band Performances" IEEE Microwave and Wireless components letters, vol. 16, no. 8, august 2006.

[3] Lei Zhu,Sheng Sun and Wolfgang Menzel, "Ultra-Wideband (UWB) Bandpass Filters Using Multiple-Mode Resonator", *IEEE Microwave and Wireless Components Letters*, Vol. 15, no. 11, pp. 796-798, NOV 2005.

[4] Hang Wang, Lei Zhu and Wolfgang Menzel, "Ultra-Wideband Bandpass Filter With Hybrid Microstrip/CPW Structure", *IEEE Microwave and Wireless Components Letters*, Vol. 15, NO. 12, pp. 844-846, DEC. 2005

[5] Qing-Xin Chu, Xiao-Hu Wu, and Xu-Kun Tian, "Novel UWB Bandpass Filter Using Stub-Loaded Multiple-Mode Resonator", *IEEE Microwave and Wireless Components Letters*, Vol. 21, No. 8, pp. 403-405, AUG. 2011.

[6] Xiao-Hu Wu, Qing-Xin Chu, Xu-Kun Tian, and Xiao Ouyang, "Quintuple-Mode UWB Bandpass Filter With Sharp Roll-Off and Super-Wide Upper Stopband" *IEEE Microw. Wireless Compon. Lett.*, vol. 21, no. 12, pp. 661--663, Dec. 2011.

[7] Zhebin Wang, Fathi Nasri, and Chan-Wang Park "Compact Tri-band Notched UWB Bandpass Filter Based on Interdigital Hairpin Finger Structure" 2011 Crown

[8] Xiu Yin Zhang, Yao-Wen Zhang and Quan Xue, "Compact Band Notched UWB Filter Using Parallel Resonators With a Dielectric Overlay", Microwave and Wireless Components Letters, Vol. 23, No. 5, pp. -252-254, May 2013.

[9] H. Zhu, Q.-X. Chu & X.-K. Tian, "Compact UWB bandpass filter using folded-T-shaped resonator with a notch-band", *Journal of Electromagnetic Waves and Applications*, Vol. 26, No. 10, pp. 1366–1373, July 2012.

[10] Min-Hang Weng, Chihng-Tsung Liauh, Hung-Wei Wu and Steve Ramrez Vargas, "An Ultra-Wideband Bandpass Filter With an Embedded Open-Circuited Stub Structure to Improve In-Band Performance" *IEEE Microwave and Wireless Components Letters*, Vol. 19, NO. 3, pp. 146-148, March 2009.

[11] Chan Ho Kim and Kai Chang, "Ultra-Wideband (UWB) Ring Resonator Bandpass Filter With a Notched Band", *IEEE Microwave and Wireless Components Letters*, Vol. 21, No. 4, pp. 206-208, April 2011.

[12] Pankaj Sarkar, Rowdra Ghatak, Manimala Pal, and D. R. Poddar, "Compact UWB Bandpass Filter With Dual Notch Bands Using Open Circuited Stubs" *IEEE Microwave and Wireless Components Letters*, vol. 22, no. 9, pp. 453-455, September -2012.

[13] M. Makimoto and S. Yamashita, *Microwave resonators and Filters for Wireless Communication*, Springer, 2003.

[14] J.S. Hong and M.J. Lancaster, *Microstrip Filters for RF/Microwave Applications*, New York; Wiley, 2001.