Design of Planar Bandpass Filter with Wide Upper Stopband for Ultra Wideband Applications

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ABSTRACT
This paper proposed a planar microstrip ultra wideband (UWB) bandpass filter (BPF) with wide upper stopband designed for applications in UWB wireless communication as stated by Federal Communications Commission (FCC). The proposed UWB filter is realized with a basic multiple mode resonator (MMR) structure feed by interdigital coupled lines for achieving higher degree of coupling. To achieve a wide upper stopband a sharp cutoff 3rd order Low Pass filter is cascaded with MMR. This filter is designed on RT/Duroid 6010 substrate of thickness 1.27 mm with Dielectric constant 10.2. The electromagnetic simulation software, Computer Simulation Technology Microwave Studio (CST MWS) is used for the simulation and analysis of the designed structure. The insertion loss of proposed filter is less than 0.2 dB at 6.8 GHz and very flat over whole pass band (3.1-10.6 GHz) also return loss is greater than 12 dB in the passband. By adding the low pass filter, the upper stopband is extended upto 20 GHz.

Keywords
Ultra Wide Band; Upper Stopband; Interdigital; Multiple Mode Resonator; Low Pass Filter; Microstrip.

1. INTRODUCTION
Ultra-wideband (UWB) radio technology has been getting popularity for high-speed high-data wireless connectivity since the federal communications commission (FCC)'s decision to permit the unlicensed operation band from 3.1 to 10.6 GHz in February 2002. With tremendous progress in ultra-wideband (UWB) technology, it has become very imperative to explore various planar band pass filters with specified ultra wide pass band [1-2].

Since then, Ultra-wideband (UWB) technology has been developed significantly many kinds of wideband filters structures have been studied: ring resonator structure; hybrid microstrip/coplanar-waveguide (CPW) structure[4]; multiple-mode resonator (MMR) structure[5]. To achieve low cost and easy integration, these filters are usually implemented in a microstrip or coplanar waveguide technology. They are designed with stepped impedance resonators and coupled lines as inverters for smaller size and increased rejection.

For designing full band ultra wideband bandpass filter we have to fulfill few requirements which are as:

- Ultra wide 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) [7].

Recently more and more research has been carried out to explore UWB Band Pass Filter (BPF) based on Multiple Mode Resonator (MMR) [3]-[4]. Recently high selective UWB BPFs are reported to improve sharpness and the in band performance of the filter by increasing and properly placing resonating mode in UWB passband and placing two transmission zeros at upper and lower band edges[8-9]. However the MMR designs are always affected by spurious bands at 2*f0*, 3*f0* of the central frequency *f0* of the MMR which degrades the upper stopband performance.

In this paper, we are presenting here a compact and high selectivity planar UWB bandpass filter for wireless communication applications with a wide upper stopband to solve the problem of spurious modes in the MMR based designs. Fig.1 shows the proposed filter structure. All dimensions of this filter are presented in TABLE I.

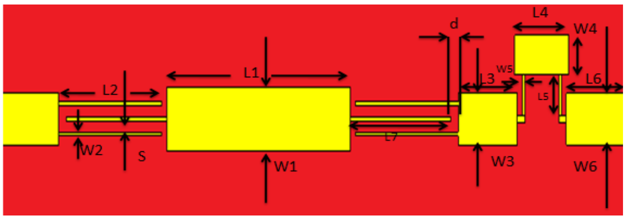


Fig 1: Configuration of the proposed UWB bandpass filter

Table I. Dimension of Proposed Filter

Filter parameter	Value	Filter parameter	Value
L_1	7.5mm	W_1	1.6mm
L_2	4.2mm	W_2	0.1mm
L_3	2.4mm	W_3	1.2mm
L_4	2.2mm	W_4	1mm
L_5	1mm	W_5	0.1mm
L_6	2.4mm	W_6	1.2mm
L_7	4.1mm	S	0.2mm
D	0.3mm		

The designing of UWB bandpass filter using the MMR feed by interdigital coupled lines for achieving higher degree of coupling and the design of compact 3rd order low pass filter at the cutoff frequency of 10.6 GHz are reported in section-II. In the section-III, the simulated results of the designed filter are shown and discussed.

2. FILTER DESIGN

The layout of the proposed UWB BPF filter is shown in Fig.1. The basic UWB band pass filter is designed using a MMR structure based on stepped impedance resonator [3]. MMR structure has its drawbacks of poor upper stopband response. Some higher order modes which arise after the higher cutoff of UWB passband restricts to achieve wide upper stop band characteristics. To suppress the higher order harmonics a sharp cutoff lowpass filter is designed with cutoff frequency 10.6 GHz.

This filter is designed on the RT/Duroid 6010 substrate with the dimension of 25.5X 8 mm2 and the thickness of 1.27mm. The RT/Duroid substrate which is used for the designing of filter has the relative permittivity of 10.2. The detail design Procedure of designing a UWB bandpass and lowpass filter is described here.

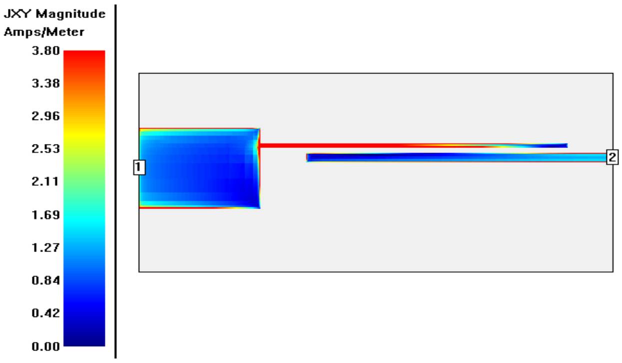
2.1 Design of UWB Bandpass Filter Section

Fig. 2 describes the schematic of the proposed microstrip-line UWB bandpass filter. At the central frequency of the UWB passband, i.e., 6.85 GHz, the MMR structure composed 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. The low impedance section is 42.92 Ω and high impedance section of the MMR is 101.02 Ω resulting in an impedance ratio of 2.35. Impedance ratio greater than 1 is utilised to design UWB filters.

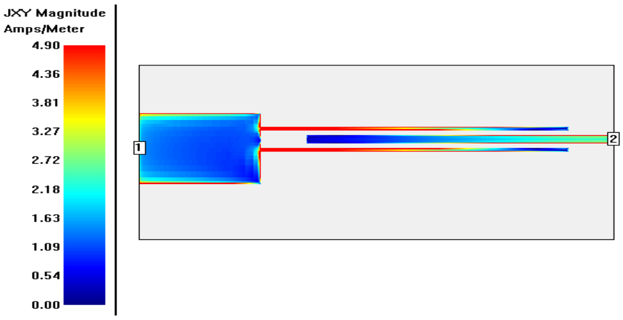
Here the length and width of interdigital lines are optimized. When we increase the length of central resonator L7 in the interdigital lines from 3.8mm to 4.3mm the selectivity of BPF is increased but central frequency gets changed.

So we optimize it to 4.1 mm for better result. As well as we optimize the length of interdigital feed lines L2 to 4.2 mm for better selectivity.

In this design, Interdigital coupled lines is used as a I/O feed lines. When giving energy to the MMR coupling energy of interdigital coupling is high compared with the single line parallel coupling. The current density results are shown in Fig.3. 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 3. (a) Current density distribution under single parallel line coupling. (b) Current density distribution under interdigital coupling.

2.2 Design of Low Pass Filter Section

A 3rd order stepped impedance lowpass filter is designed at cutoff frequency 10.6 GHz. The order of the filter is selected three to reduce the area requirement and we arrange it in a manner to compact the size. The equivalent circuit model is presented to understand the operation of proposed LPF. The layout of the filter along with the equivalent circuit is shown in Fig.4. A 3rd order LPF consists of two symmetric high impedance section of equivalent inductance L1=0.967 nH and one low impedance section at the middle of corresponding capacitance C1= 0.64 *pF*.

The simulated frequency response of the lowpass filter is plotted in Fig. 5. The S11 parameter of the filter is less than -13 dB throughout the pass band with S21 parameter is moe than 0.5 dB. 14dB attenuation at stopband provides significant rejection of signal level. Finally the lowpass filter is combined with the MMR structure to achieve UWB band pass filter with wide upper stop band.

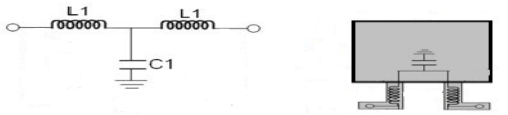


Fig 4. Layout and equivalent circuit of proposed low pass filter

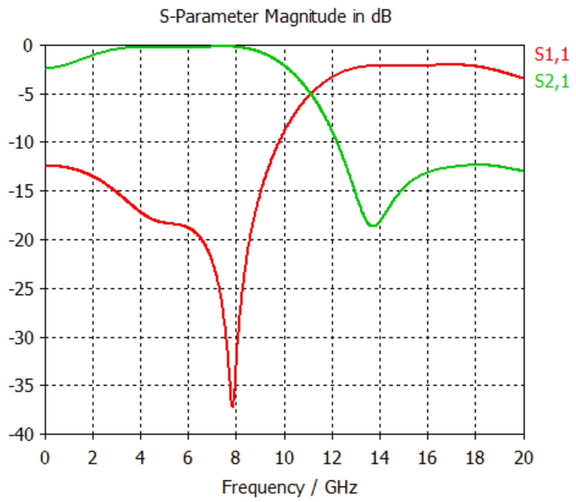
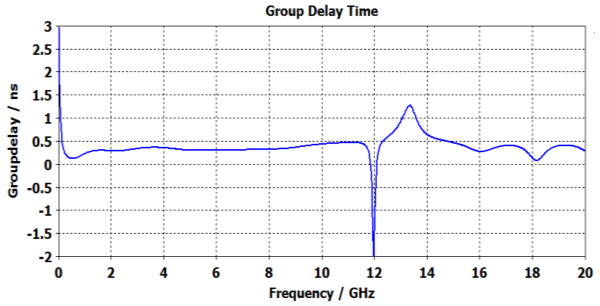


Fig 5. Simulated frequency response of low pass Filter section

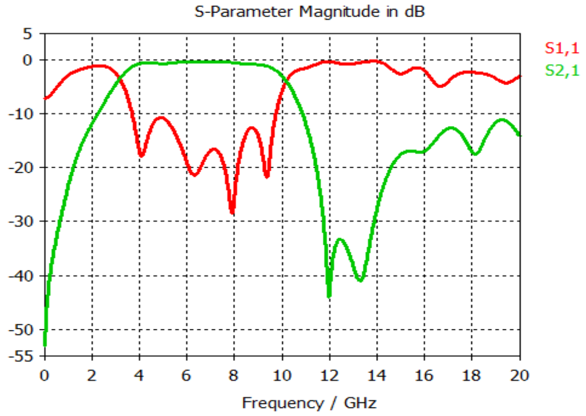
3. SIMULATION AND RESULTS

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

The return loss and insertion loss is shown in this Fig 6(b). The proposed filter is working on whole ultra wide band from 3.1 GHz to 10.6 GHz, which shows return loss less than -10 dB and insertion loss of this filter is more than -0.5 dB for whole ultra wide band. The insertion loss is very flat over the whole band. The upper stopband is extended up to 20 GHz with minimum 12dB attenuation at stopband provides significant rejection of signal level. Group delay of this filter is flat less than 0.4ns in the passband.



(a)



(b)

Fig 6. Simulated Frequency Response of UWB filter (a) Group Delay (b) S-Parameters (S_{11} and S_{21})

4. CONCLUSION

This paper presents a compact UWB bandpass filter with wide upper stopband. A cascaded topology of MMR structure with a low pass filter is implemented. 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. By using low pass filter we achieved a wide upper stopband up to 20 GHz in a limited space considering the issue of compactness. The overall performance and Characteristic of designed filter is excellent and can be useful for any modern wireless device.

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