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A Compact Band-Pass Filter (BPF) With Notched Band for Ultra-Wideband (UWB) Wireless Communications

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ABSTRACT

A new low-profile band-pass filter (BPF) with single and variable notched-band is presented for ultra-wideband (UWB) wireless communications. The schematic of the proposed BPF is composed of a stepped-impedance open stub and short stub loaded multi-mode ring resonator (MMR). It is designed on a compact and low-cost FR-4 substrate with properties of ε= 4.3, δ= 0.025, and h=0.8 mm. the operation frequency and impedance bandwidth of the UWB passband and stopband can be easily adjusted by tuning the sizes of the proposed BPF parameters. The design procedures of the presented microstrip filter are described in detail and investigated by using CST software. The proposed BPF exhibits a wide usable fractional bandwidth from 2.8 to 11.1 GHz with a single notched band at 5.5 GHz. Due to the simple and compact profile and sufficient UWB characteristics, the proposed BPF is useful for modern UWB wireless communication systems.

Keywords: *BPF, MMR, notched band, open stub, UWB communications, wireless systems.*

INTRODUCTION

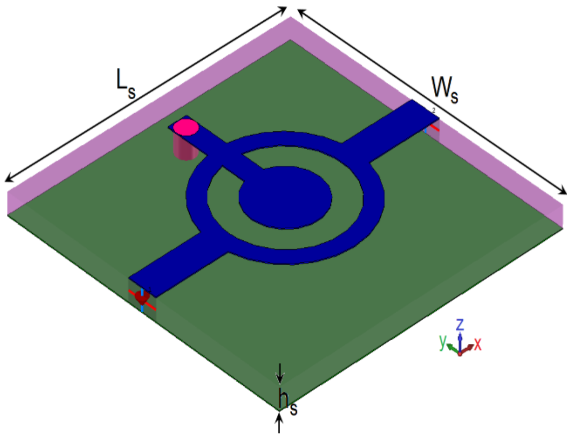
Planar microwave wideband BPF's have received greater attention due to several advantages, such as low cost, small size, and ease of fabrication. The performance of the filter highly depends on its passband and out-of-band performances [1-5].

The frequency range of 3.1-10.6 GHz has been allocated as Ultra-wideband by the federal communications commission (FCC) [6-10]. However, there are some existing narrow-band systems which have been used in communications for a long time. Furthermore, the UWB frequency band overlaps with these existing narrow communication systems, such as WLAN, WiMAX, etc [11-15]. Those narrowband radio signals might interfere with UWB systems and vice versa. To mitigate potential interference, the design of compact UWB components with notched band characteristics is one of the most challenging topics [16-17]. Consequently, several methods were proposed to design UWB BPFs with notched bands [18-20].

In this study, we propose a new compact UWB filter implemented based on the concept of stepped-impedance open stub and short stub loaded multi-mode ring resonator. The proposed BPF is operating in the frequency range of 3.1-10.6 GHz (UWB spectrum) with a notched band at 5.5 GHz Fundamental characteristics of such a bandpass filter are studied and a demonstrator is validated by simulations.

DESIGN DETAILS

The side and front view of the proposed ultra-wideband BPF is shown in Fig. 1. As can be observed, its configuration contains a stepped-impedance open stub and short stub loaded multi-mode ring resonator. It is designed on a low-cost FR-4 substrate with an overall dimension of $W_s \times L_s$= 15×15 mm^2. The EM simulation software CST Microwave Studio was used for the simulation [21]. The characteristics of the filters are obtained in terms of S-parameters, current distribution and group delay, as described in the following.



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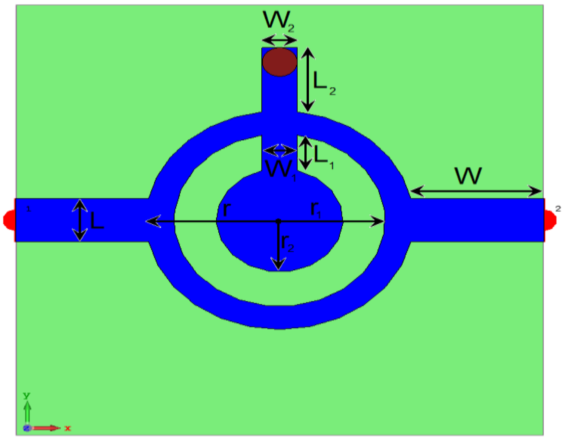

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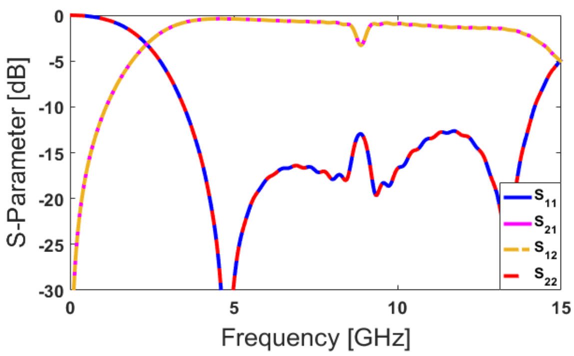
Fig1. *(a) Side and (b) front views of the proposed band-pass filter.*

Table1. *Dimensions of the Design Parameters*

Parameter	W_s	L_s	h_s	W	L	r
Value (mm)	15	15	0.8	1.5	3.75	3.8
Parameter	W_1	L_1	r_1	W_2	L_2	r_2
Value (mm)	1	1.25	3	1	2.25	1.8

Characteristics of the Proposed BPF

Figure 2 shows the different configurations of the designed band-pass microstrip filter with and without the stepped-impedance open stub. It is clearly seen that the proposed microstrip filter exhibits a good passband function over the UWB frequency range from 3.1 to 10.6. In addition, by employing the protruded stepped-impedance open stub, the proposed filter generates a single notched band at 5.5 GHz.



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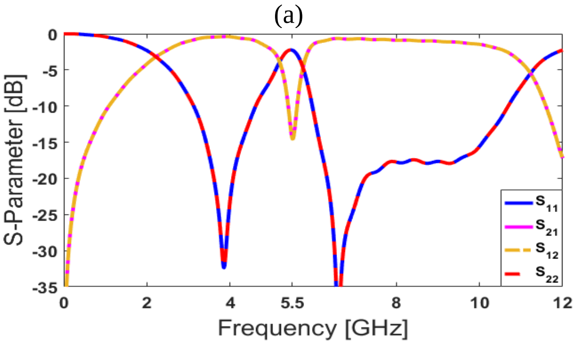

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Fig2. *S-parameter results of the filter (a) without and (b) the stepped-impedance open stub.*

In order to understand the phenomenon behind the band-notch function of the designed UWB microstrip filter, the current distribution of the design at the notched frequency (5.5 GHz) is illustrated in Fig. 3. It is evident that the employed stepped-impedance stub is highly active in generating the band-stop function in the notched frequency (5.5 GHz) [22-26]. According to the current distribution, it can be found that at the current flows are more dominant around the open-ended circular-ring of the protruded stub.

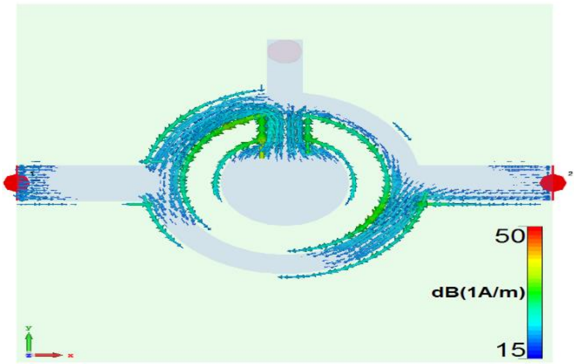
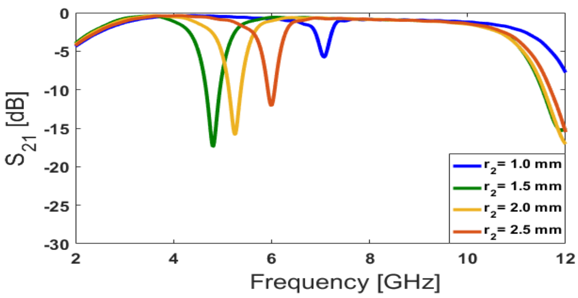


Fig3. *Current distribution at the notched frequency (5.5 GHz).*

The frequency and also the impedance bandwidth of the notched frequency band can be easily controlled by tuning the impedance ratio of the stepped-impedance open-stub, and the length of the short stub [27-30]. In order to demonstrate the flexible function of the proposed UWB microstrip band-pass filter, parametric studies are performed in the following.



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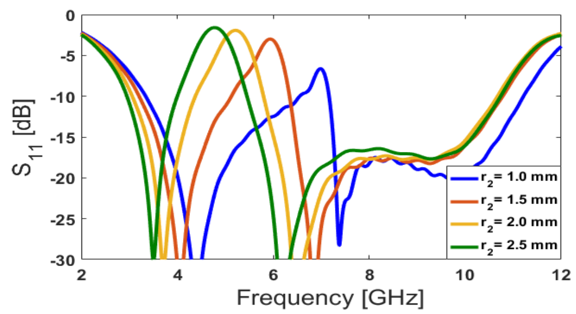
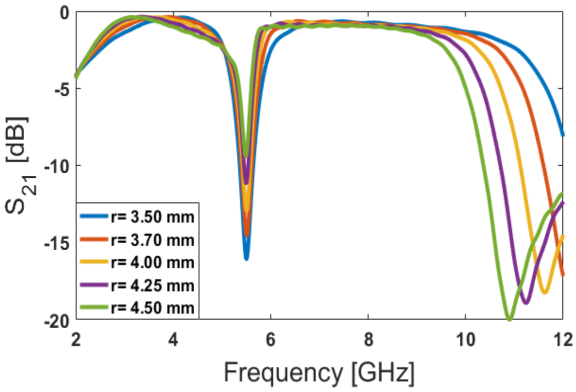


(b)

Fig4. *Simulated (a) S_{21} and (b) S_{11} results for different values of r_2.*

Figure 5 represents the simulated frequency responses (including S_{21}/S_{11} results) of the proposed microstrip filter under the different radios of r_2. We may note that the center frequency of the notched band can be easily tuned from 5.1 to 5.4, 5.75 GHz when the size of r_2 varies from 1 to 2.5 mm.



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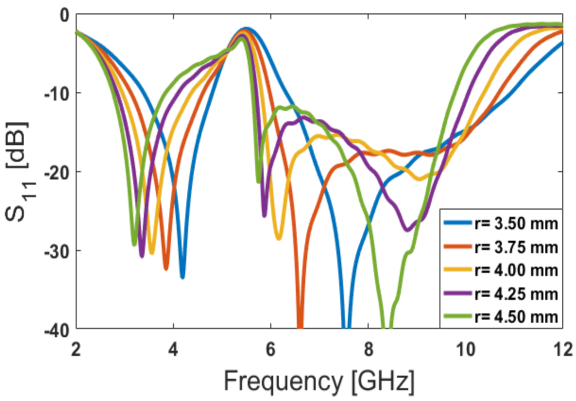


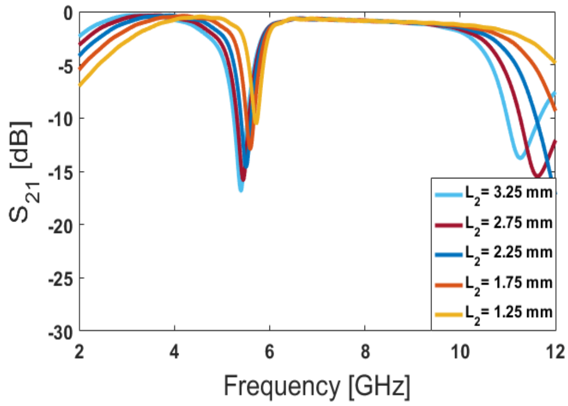
(b)

Fig5. *Simulated (a) S_{21} and (b) S_{11} results for different values of r.*

Figure 7 investigates the tuning of impedance bandwidth of the notched band. As can be observed from Fig. 7, the notched bandwidth can be varied by changing the radius of r. It is evident when the size of r changes from 3.5 to 4.5 mm, the bandwidth of the notched frequency can be changed from 0.2 to 0.6 GHz.

Another parameter that can affect both the frequency and impedance bandwidth of the notched band is the length of the protruded stub (L_2). Figure 6 investigated the frequency responses (including S_{21}/S_{11} results) of the proposed microstrip filter for different values of L_2. As can be observed, changing the size of L_2 from 3.25 to 1.25 mm, not only affect the operation frequency but also the bandwidth of the notched band [31-35]. It is shown that operation frequency and bandwidth of the notched band can be tuned from 5.9 to 5.5 GHz and 0.2 to 0.7 GHz, respectively.

The group delay characteristic of the proposed filter has been shown in Fig. 7, resulting in slight variation between 0.2 to 0.3 ns in the passband. In addition, the wide range response of the upper stopband can be seen. Furthermore, at the notch frequency, a sharp reduction can be observed [36-40].



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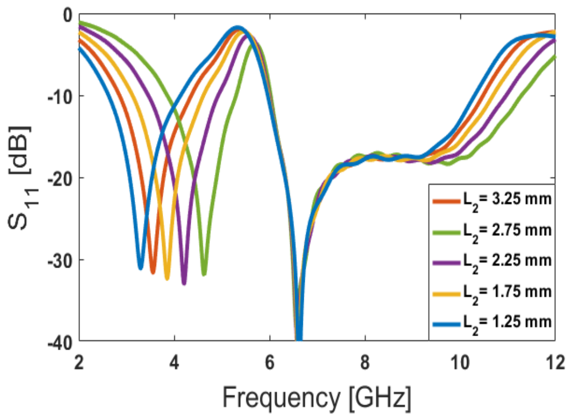

(b)

Fig6. *Simulated (a) S_{21} and (b) S_{11} results for different values of L_2.*

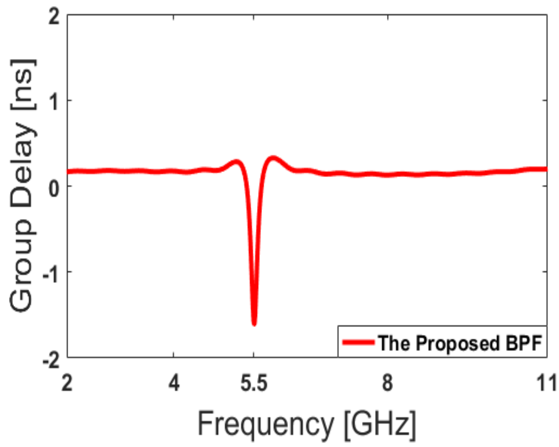

Fig7. *The simulated group delay of the proposed BPF.*

Conclusion

A compact design of the bandpass microstrip filter with a variable notched-band function has been introduced for UWB communications. The proposed BPF exhibits a wide usable fractional bandwidth from 3.1 to 10.6 GHz with a single notched band at 5.5 GHz.

Acknowledgments

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