A Design of UWB Band-Pass Filter with Variable Dual Notched Bands Using EBG Structure

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Abstract. A new design of band-pass filter (BPF) with variable dual notched bands characteristic is introduced for ultra-wideband (UWB) applications. The configuration of the proposed BPF contains a rectangular-ring stub loaded with parallel-coupled lines and an inverted T-shaped electromagnetic band-gap (EBG) resonator is proposed in this letter. It is designed on a Rogers 5880 substrate with properties of ε= 2.2, δ= 0.0009, and h=1 mm. The proposed BPF exhibits a wide usable fractional bandwidth from 3.1 to 10.6 GHz and two-frequency notch-bands at 5 and 8 GHz. Due to the simple configuration and excellent characteristics of the presented design with tubule dual notch function, the proposed BPF is useful to be used in UWB communication networks.

Keywords: BPF, EBG, notched frequency, UWB communications.

1 Introduction

Ultra-wideband (UWB) technology has received much attention and became one of the most rapidly developing technologies in wireless applications due to its inherently attractive advantages including low power, high transmission rate, and so on [1-7]. The UWB band-pass filter (BPF) is one of the critical components in realizing an UWB system, which has attracted more attention recently [8-10].

The congestion of the frequency spectrum and the interference of various communication systems are considered the most important problems due to the advancement of wireless systems and the sustainable demand for improving the operation bandwidth. The operation frequency spectrum of 3.1-10.6 GHz was allocated as ultra-wideband by the federal communications commission (FCC) [11]. However, there are some narrow-band wireless systems that have been used in communications for a long time. Furthermore, the UWB frequency band overlaps with these existing narrow systems, such as WLAN, WiMAX, and etc. Those narrowband radio signals might interfere with UWB systems.

To mitigate potential interference, the design of compact UWB components with notched band characteristics is one of the most challenging topics [12-15]. Consequently, several methods were proposed to design UWB BPFs with notched bands [16-17]. In this manuscript, we propose a new approach to design an UWB BPF with good dual notched bands function. This function is obtained by using a ring-stub multi-mode resonator (RSMMR). The resonance

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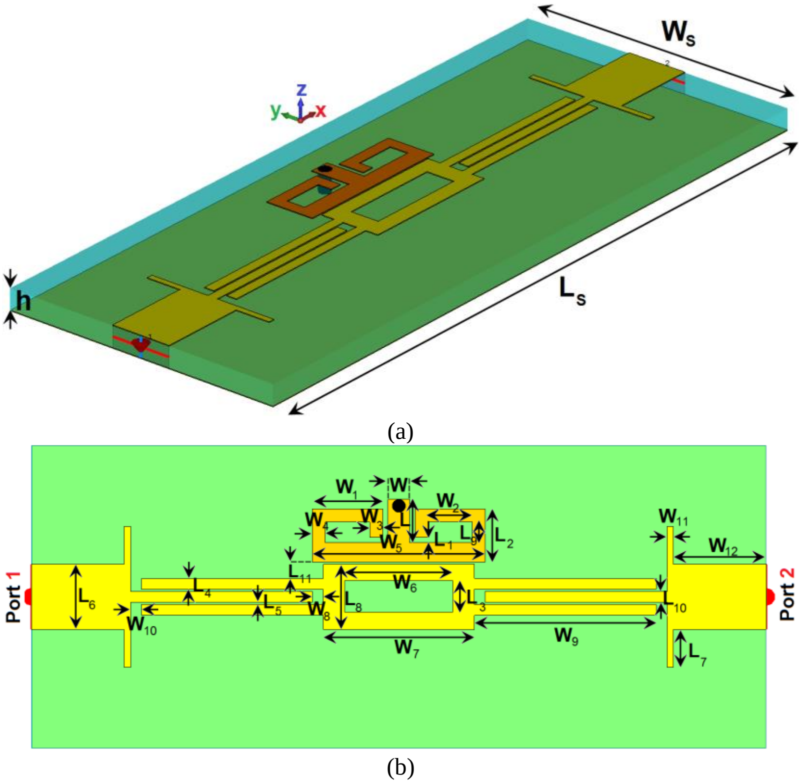
condition of RSMMR is obtained by embedding a modified EBG with an inverted T-shaped configuration [18]. The BPF is operating in the range of 3.1-10.6 GHz (UWB spectrum) with two notch bands at 5 and 8.0 GHz.

2 Schematic of the Proposed BPF Design

The geometry of the proposed microstrip filter is illustrated in Fig. 1. As can be observed, its configuration is composed of a rectangular-ring stub loaded with parallel-coupled lines and inverted T-shaped EBG resonator. While designing BPFs, one of the challenges is to design the filter in a compact area with high performance [19-24]. It is designed on a low-loss Rogers 5880 dielectric. The EM simulation CST software was used for the simulation [25].



(a)

(b)

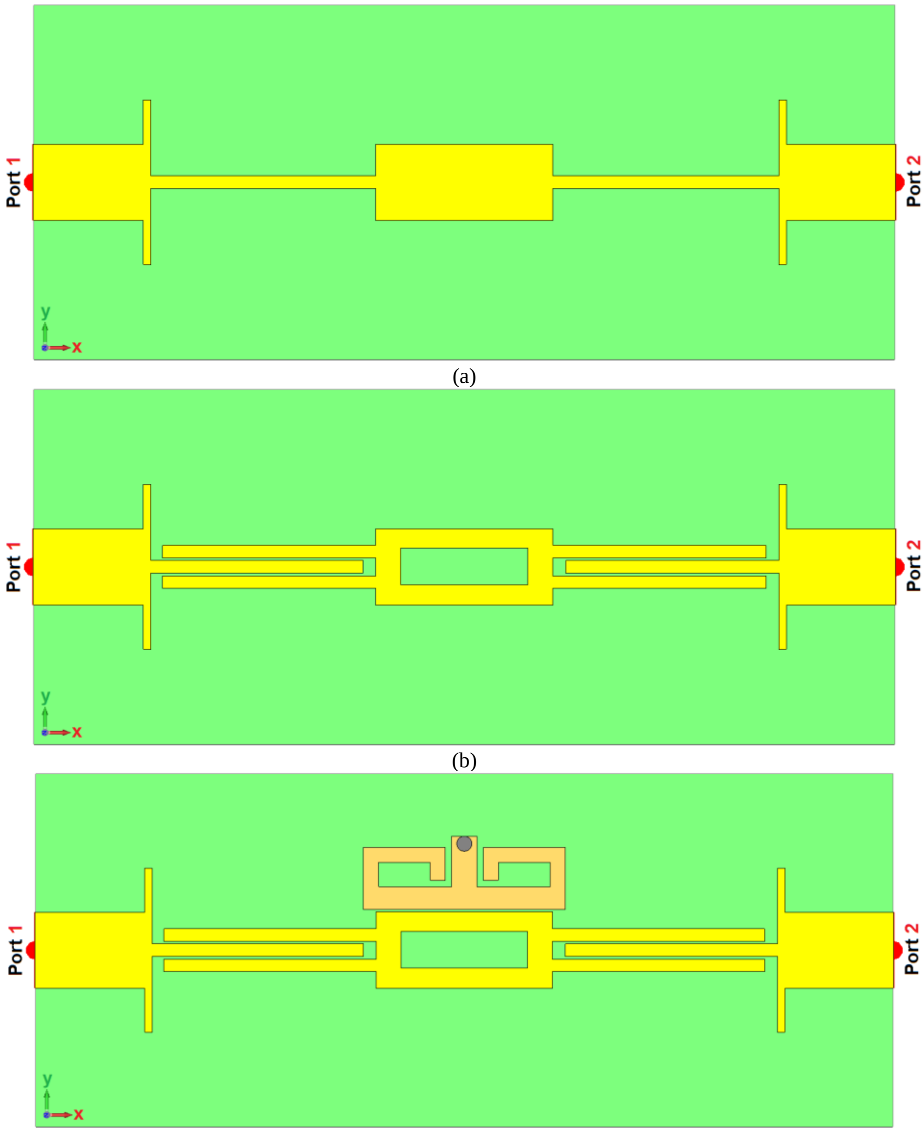
Fig. 1. (a) Side and (b) front views of the ultra-wide BPF.

Table 1. Dimensions of the BPF parameters.

Param.	W_S	L_S	W	L	W_1	L_1	W_2	L_2	W_3
(mm)	14	34	1	2	3.25	0.25	2	2.5	3.5
Param.	L_3	W_4	L_4	W_5	L_5	W_6	L_6	W_7	L_7
(mm)	1.5	0.6	0.5	8	0.1	5	3	7	1.75
Param.	W_8	L_8	W_9	L_9	W_{10}	L_{10}	W_{11}	L_{11}	W_{12}
(mm)	0.5	3	8.4	1	0.5	0.5	0.3	0.75	4.3

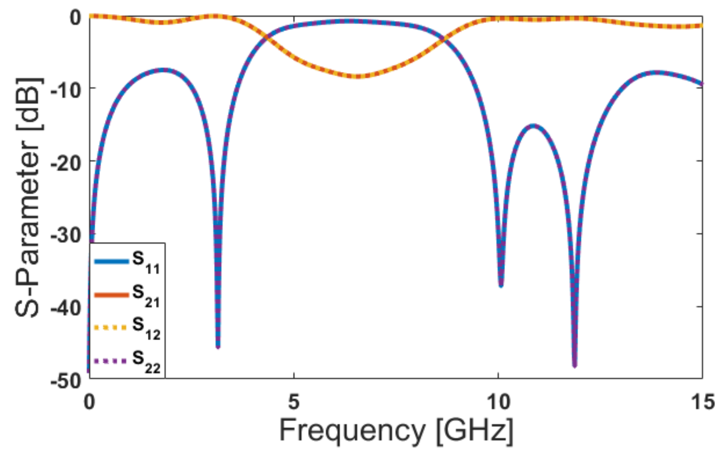
2 Characteristics of the Presented Microstrip Filter

Figure 2 shows the different configurations of the designed band-pass microstrip filter. As shown, the schematic of the basic design (Fig. 2 (a)) contains a rectangular stub with modified strips. As seen, in the second step, the configuration of the filter design is modified to contain a rectangular-ring stub loaded with parallel-coupled lines. Finally, an inverted T-shaped EBG resonator is added in the configuration of the proposed microstrip filter [26-28]. The S-parameters illustrated in Fig. 3 have been discussed in Fig. 4.

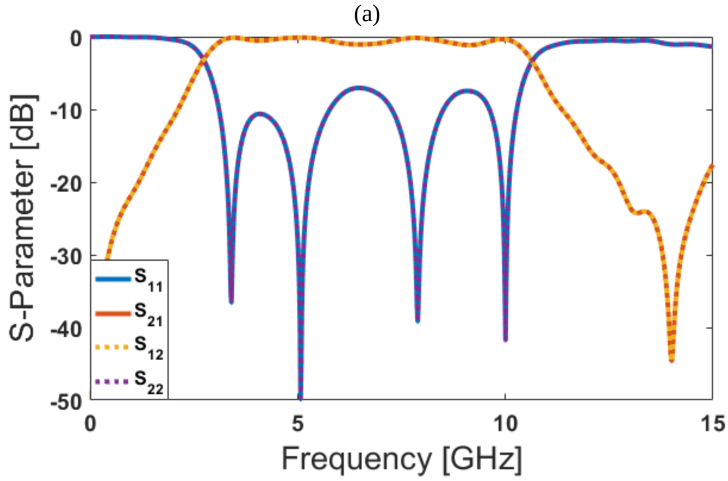


(c)

Fig. 2. (a) The basic structure (b) modified BPF, and (c) the final configuration of the BPF.



(a)



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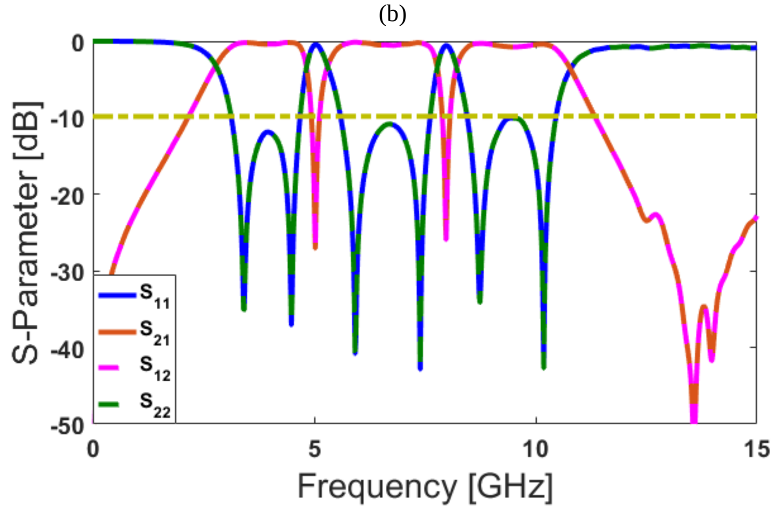


(c)

Fig. 3. S-parameters of the BPF for different (a) 1, (b) 2, and (c) 3 configurations shown in Fig. 3.

According to the obtained results shown in Fig. 3 (a) and (b), by modifying the structure of the filter, a sufficient band-pass function covering the UWB spectrum can be achieved. This is mainly due to the loading with parallel-coupled lines which could act as a multiple-mode resonator (MMR). Finally, as shown in Fig. 3 (c), by adding the proposed EBG structure, the proposed filter not only generates a good dual band-stop function at 5 and 8 GHz but also improves its UWB band-pass function. The current distributions at the first and second frequency notches are illustrated in Fig. 4. It is evident that the employed EBG is highly active in generating notches [29-34]. According to the current distribution at 5 and 8 GHz, it can be found that at the first notch, the currents are extremly active inside the EBG and at 8 GHz, the outer width of the EBG is surrounded by the surface current.

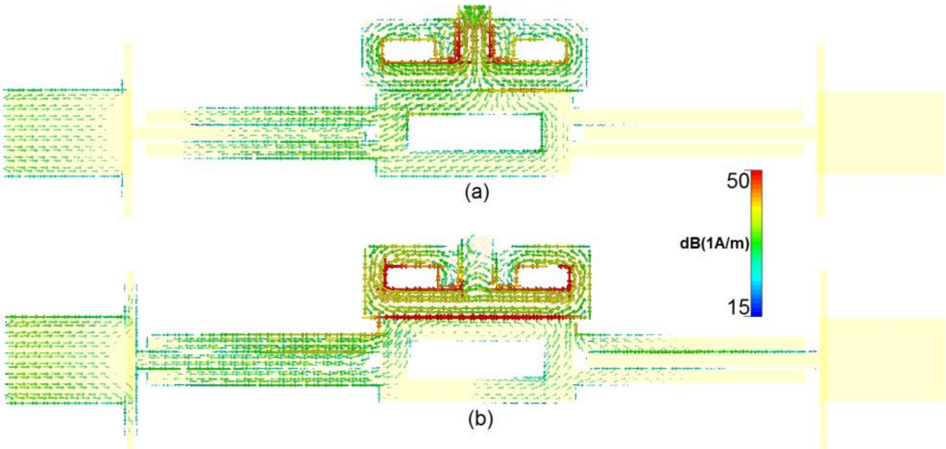


Fig. 4. Current distributions at the nothces, (a) 5 GHz and (b) 8 GHz.

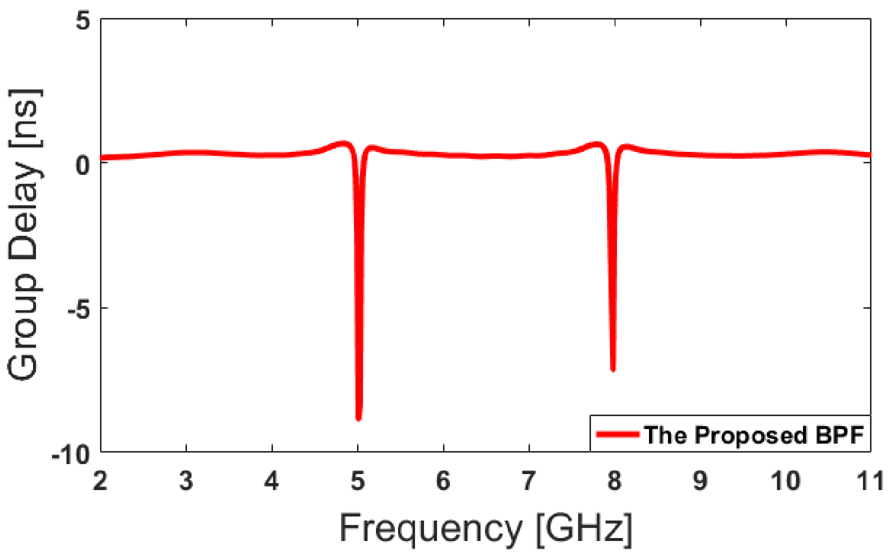
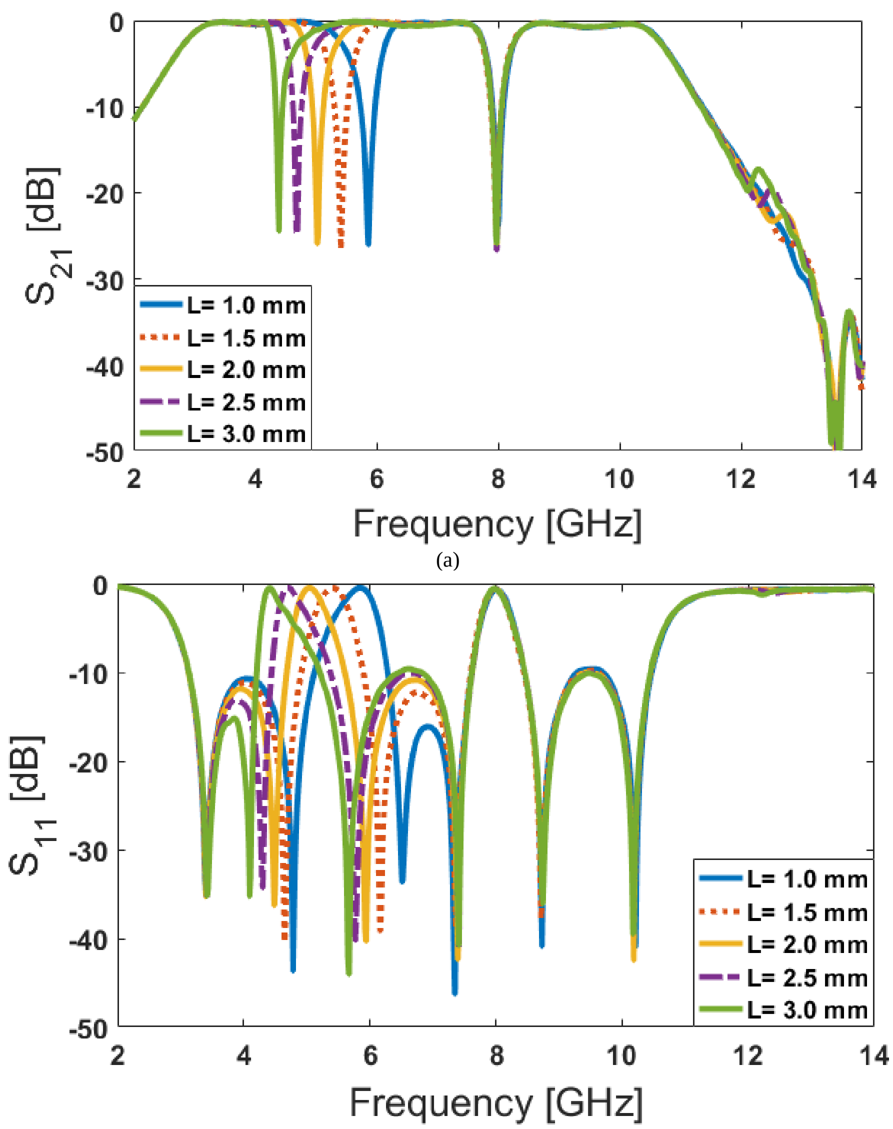


Fig. 5. The group delay function.

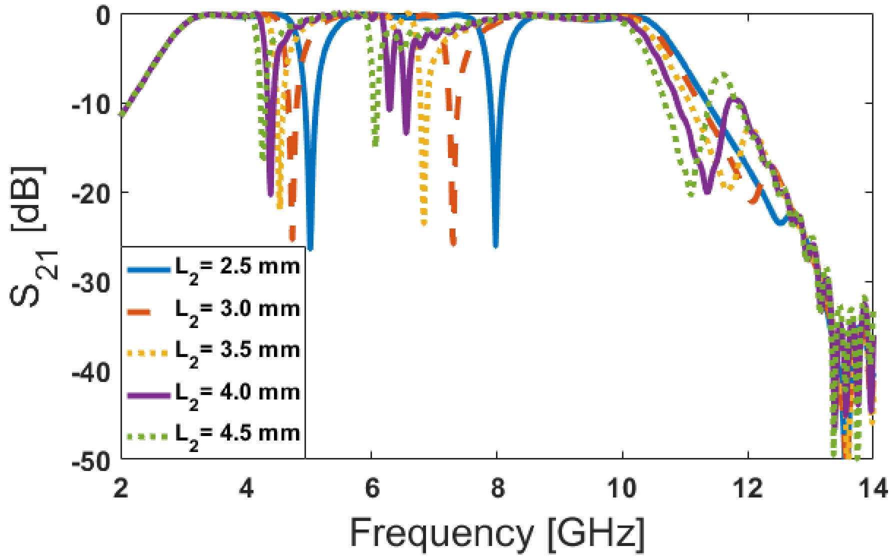
The group delay characteristic of the proposed filter has been shown in Fig. 5, resulting in slight variation between 0.5 to 1 ns in the passband. In addition, the wide range response of the upper stopband can be seen. Furthermore, at the notch frequencies, sharp reduction can be observed [35-37]. In order to demonstrate the variable function of notch frequencies, parametric studies are performed in the following. The first notch frequency of the UWB filter is significantly altered by tuning the size of the rectangular arm (L) of the employed EBG. The S_{21}/S_{11} results of the design for values of L are represented in Fig. 6. As seen in Figs. 6 (a) and (b) when the size of L increases from 1 to 3 mm, the first notch easily tunes from 5.8 to 4.2 GHz.



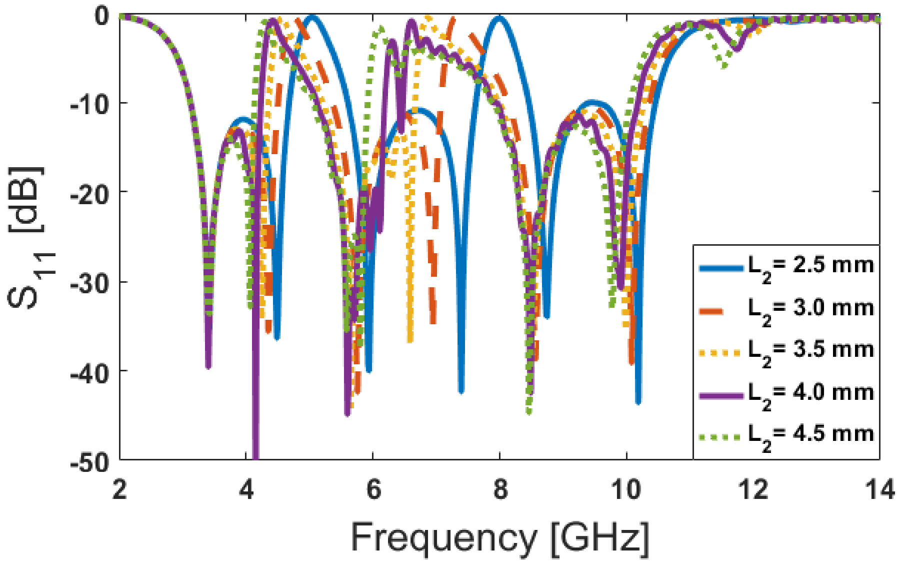
(b)

Fig. 6. (a) S_{21} and (b) S_{11} results for various L values.

Figure 7 investigates the tuning of both notch frequencies. As shown in Fig. 7, by changing the outer length of the EBG (L2), the first and second notch frequencies can be tuned simultaneously. According to the obtained S_{21}/S_{11} results for different values of L it is clear when the size of L_2 increases from 2.5 to 4.5 mm, the first notch frequency can be easily decreased from 5 to 4 GHz and the second notch tunes from 8 to 6 GHz. According to the obtained results, we can conclude the notch frequencies can be easily tuned and modified to avoid the interferences from various wireless systems with operation frequency within the UWB spectrum [38-40].



(a)



(b)

Fig. 7. (a) S_{21} and (b) S_{11} results for different values of L_2.

Conclusion

In this study, new band-pass filter with UWB performance and dual notched bands is designed and its characteristics are investigated. Its structure contains a rectangular-ring stub with parallel-coupled lines and also an inverted T-shaped EBG. The proposed design provides an UWB passband bandwidth, ranging from 3.1 to 10.6 GHz. It also exhibits two-sharped frequency notch-bands at 5 and 8 GHz. The design has been successfully accomplished and verified by the simulations and could be used in UWB applications.

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