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A New Design of Low-Profile Band-Pass Filter for Ultra-Wideband Applications

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ABSTRACT

This paper proposes a new and highly compact design of band-pass filter (BPF) for ultra-wideband (UWB) applications. The schematic of the proposed BPF is composed of two coupled E-shaped stubs loaded in the top layer and defected ground structure (DGS) in the back layer. It is designed on an 8×8 mm2 Rogers 40030C substrate with properties of ε= 3.38, δ= 0.0027, and h=0.508 mm. High performance achieved by the proposed UWB filter is validated by simulations. The design procedures 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. Due to the simple and compact profile and sufficient UWB characteristics, the proposed BPF is useful for modern UWB wireless communication systems.

Keywords: *BPF, coupled stub, DGS, UWB, wireless communications.*

INTRODUCTION

The microwave filters play a very important role in wireless and satellite communication transceiver systems. It is an important passive component in the communication system that rejects unwanted signals in the specified band of interest [1-4]. 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 [5-10].

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 [11-16]. The frequency range of 3.1-10.6 GHz has been allocated as Ultra-wideband by the federal communications commission (FCC) [17]. The UWB band-pass filter (BPF) is one of the key passive components to realize a UWB radio system which has attracted more attention recently. Consequently, a number of methods were proposed to design UWB BPFs [18-20].

It this study, we propose a new compact UWB filter implemented based on the concept of modified/coupled stub and DGS. It provides a wide usable fractional bandwidth from 2.8 to 11.1 GHz. Fundamental characteristics of such a bandpass filter are studied and a demonstrator is validated by simulations.

DESIGN DETAILS

The configuration of the proposed ultra-wideband band-pass microstrip filter is illustrated in Fig. 1. As can be observed, its configuration coupled E-shaped stubs in the top layer and a modified DGS in the ground plane. It is designed on a low-loss Rogers 40030C dielectric. 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.

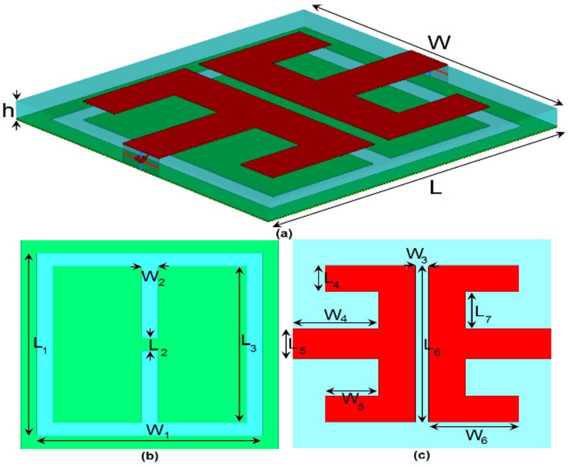


Fig1. *(a) Side, (b) Back, and (c) top view of the proposed microstrip band-pass filter.*

Table1. *Dimensions of the Design Parameters*

Parameter	W	L	h	W_1	L_1
Value (mm)	8	8	0.508	7	7
Parameter	W_2	L_2	W_3	L_3	W_4
Value (mm)	0.5	0.5	6	0.5	2.65
Parameter	L_4	W_5	L_5	W_6	L_6
Value (mm)	1	1.65	1.15	2.8	6

CHARACTERISTICS OF THE PROPOSED BPF

Figure 2 shows the different configurations of the designed band-pass microstrip filter.

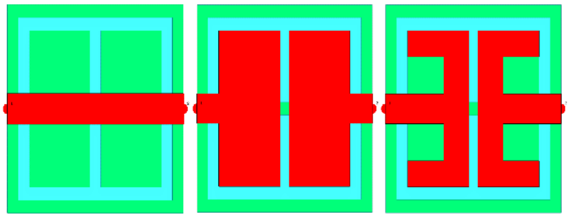


Fig2. *(a) filter design with the DGS, (b) the filter with DGS and a pair of coupled T-shaped stub, and (c) the proposed filter design.*

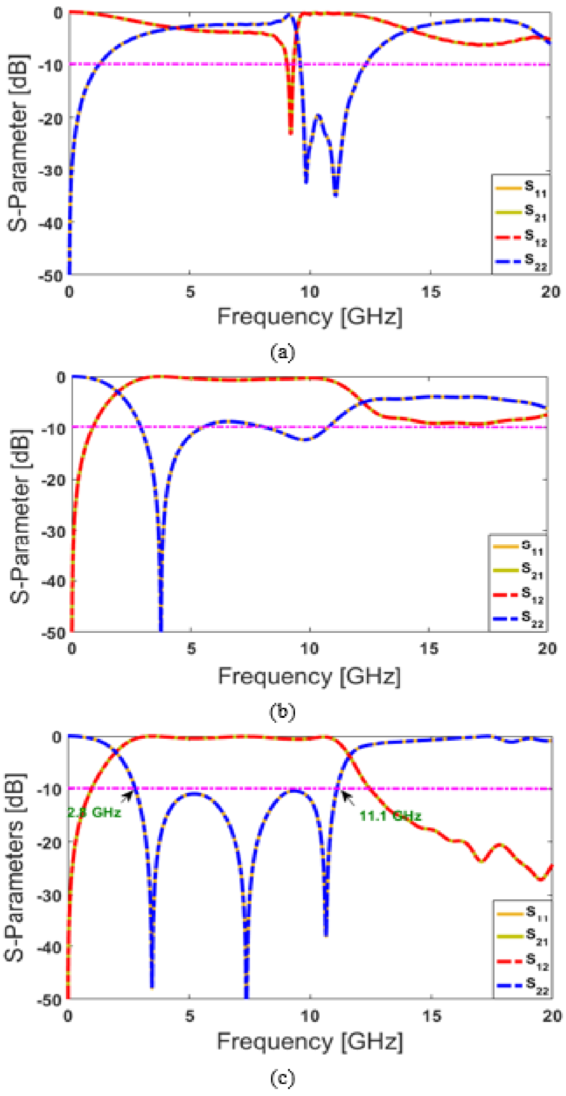


Fig3. *S-parameter results of the different filters shown in Fig. 3.*

As shown, the schematic of the basic design (Fig. 2 (a)) contains a transmission line with the proposed DGS. In the second step, a pair of coupled T-shaped stubs are used in the top layer (Fig. 2 (b)). Finally, the stubs are converted to E-shaped structures in the configuration of the proposed microstrip filter, as shown in Fig. 2 (c).

According to the obtained results shown in Figs. 3 (a), using the proposed DGS in the bottom layer of the conventional 2-port transmission line, the design can exhibit a good band-pass around 10 GHz. It is shown in Fig. 3 (b), that by employing the coupled T-shaped stub, the designed filter is generation a passband covering 3 GHz to 10 GHz. Finally, by modifying the configuration of the stub to the pair of coupled E-shaped stubs, a good band-pass function covering the UWB spectrum in the frequency range of 2.8 GHz to 11.1 GHz can be achieved for the proposed microstrip filter [22-26].

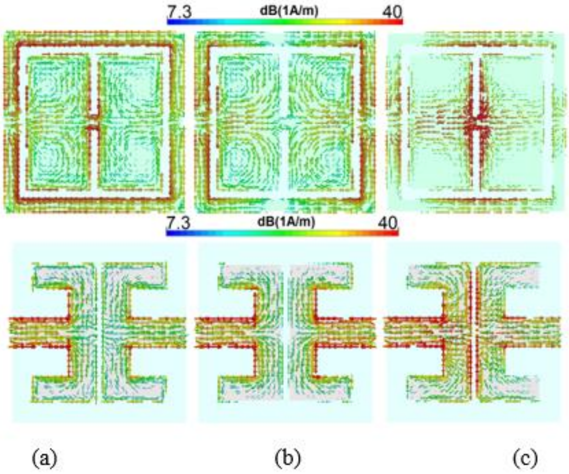
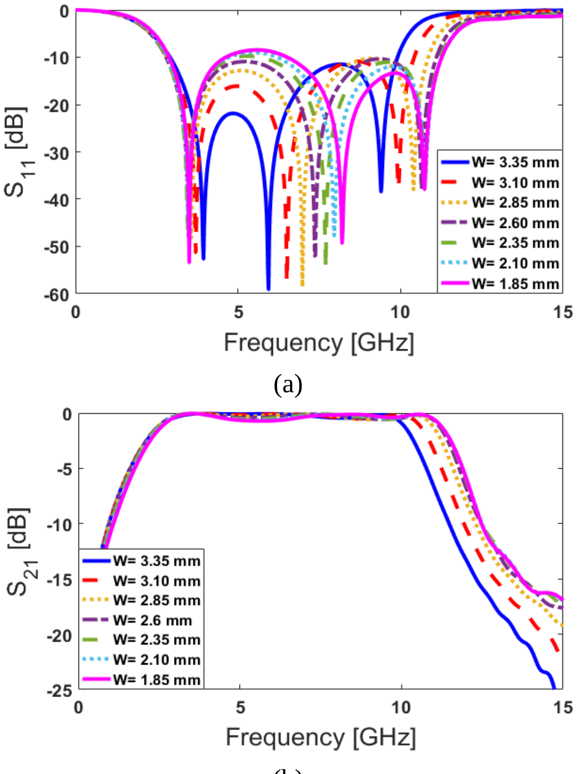


Fig4. *Current distributions at, (a) 3.8 GHz, (b) 7.4 GHz, and (b) 10.5 GHz.*

In order to understand the phenomenon behind the band-pass function of the designed UWB microstrip filter, the current distributions in the top and bottom layers of the design at the different resonance frequencies including 3.8 GHz, 7.4 GHz, and 10.5 GHz are illustrated in Fig. 4. It is evident that the employed DGS is highly active in generating the resonance and the band-pass function [27-32]. According to the current distribution at 3.8 and 7.4 GHz, it can be found that at the current flows are more dominant around the square-ring of the DGS. On the other hand, at 10.5 GHz, the inner gap of the DGS is surrounded by the surface current. It is also illustrated that modifying the top layer of the designed filter to the pair of coupled E-shaped stubs, the proposed microstrip filter can provide better performance while keeping the compact-size characteristic.

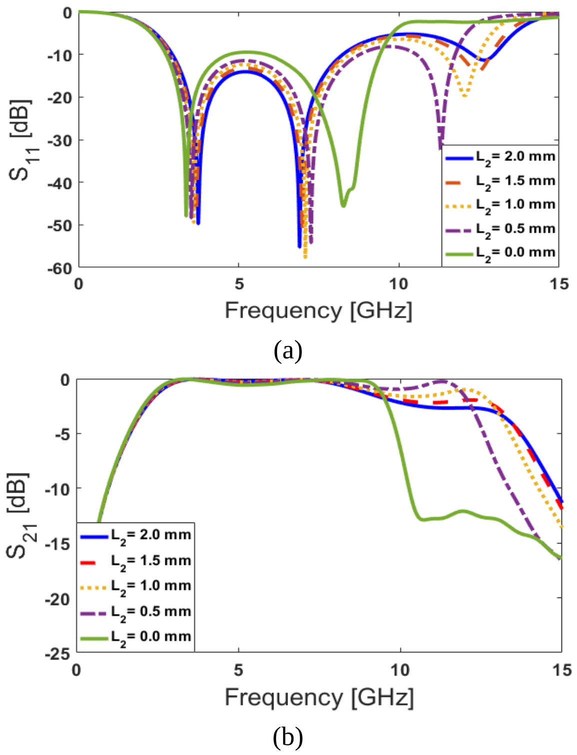
In order to demonstrate the flexible function of the proposed UWB microstrip band-pass filter, parametric studies are performed in the following. The upper band of the UWB filter is significantly altered by tuning the size of the square-ring of the employed DGS (W).



(a)

(b)

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



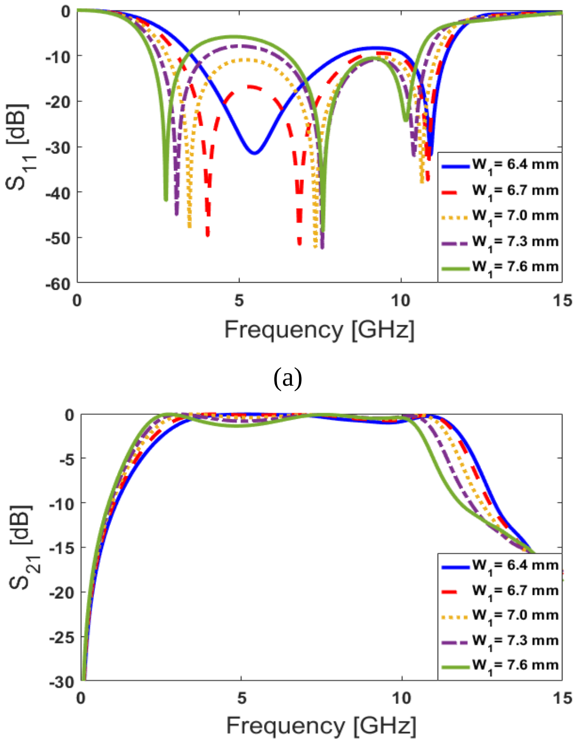
(a)

(b)

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

The S_{21}/S_{11} results of the design for different values of W are represented in Fig. 5. As shown in Figs. 5 (a) and (b) when the size of W decreases from 3.35 to 1.85 mm, the upper frequency can be easily tuned from 10 to 11.5 GHz. Another design parameter that can affect the upper band of the microstrip filter is the inner gap of the DGS placed in the ground plane [33-39]. As can be observed from Fig. 6, changing the value of L_2 from 2 to 0 mm could significantly affect the upper band function of the filer.

Changing the size of W_1 could affect both lower and upper passbands of the proposed microstrip filter. It is evident from Fig. 7 when the size of W1 increases from 6.4 mm to 7.6 mm, both lower and upper bands can be tuned to different frequencies. I can also affect the matching function of the proposed filter.



(a)

(b)

Fig7. *Simulated (a) S_{21} and (b) S_{11} results for different values of W_1*

Another important design parameters of the proposed UWB microstrip band-pass filter is the length of the coupled E-shaped stubs. The S_{21}/S_{11} results of the design for different values of L_6 are illustrated in Fig. 8. It is shown that varying the size of L6 from 7.5 to 4.5 mm leads to generate different frequency response for the proposed design [40-42]. The group delay characteristic of the proposed UWB filter has been shown in Fig. 9 resulting in a slight variation between 0.5 to 1 ns in the desired UWB passband [43-50].

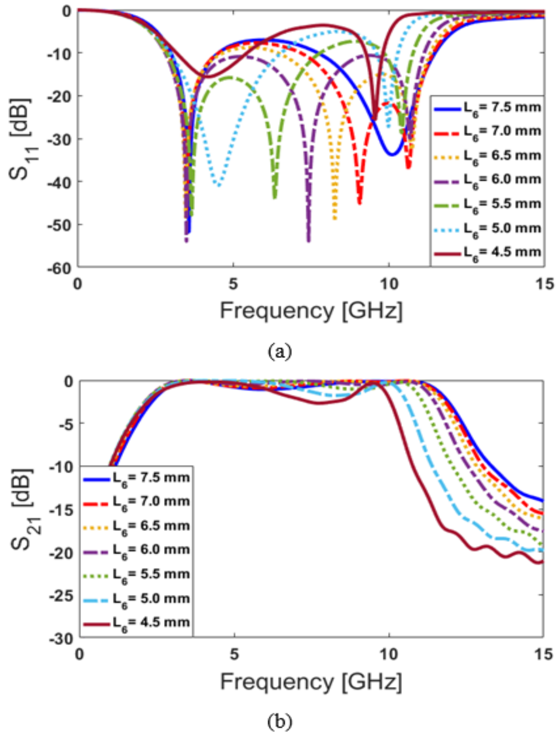


Fig8. *Simulated (a) S_{21} and (b) S_{11} results for different values of L_6.*

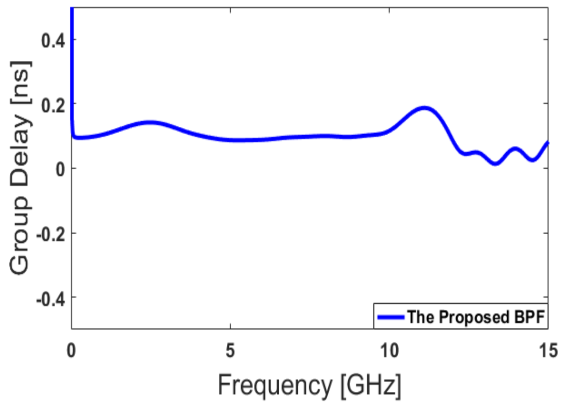


Fig9. *The simulated group delay of the proposed BPF.*

CONCLUSION

A compact design of the UWB bandpass microstrip filter has been introduced in this letter. The UWB passband function of the design was realized by using the modified stub and a DGS. The proposed filter features compact size, easy fabrication, and is suitable for UWB wireless systems.

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