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Compact Ultra-Wide Band Bandpass Filter Design Employing Multiple-Mode Resonator and Defected Ground Structure

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Abstract

A compact bandpass filter (BPF) for ultra wideband (UWB) applications is proposed in this paper. The filter is consisting of two symmetrical multiple-mode resonators (MMRs) connected to quarter-wavelength parallel coupled lines in the input and output ports on the top, and a rectangular shaped defected ground structure (DGS) on the bottom of the filter. This filter provides in the passband an insertion loss of 0.2 dB and a return loss greater than 17 dB. Furthermore, the filter occupies an area of 10.42 x 2 mm². The simulation results are in satisfactory agreement with the measurement ones reported elsewhere. The proposed UWB-BPF presents good performances in terms of insertion loss, return loss, fractional bandwidth and compact size than those reported in the literature.

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Keywords: Ultra wideband (UWB); Bandpass filter (BPF); Multiple-mode resonator (MMR); Defected ground structure (DGS)

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1. Introduction

Ultra-wideband (UWB) technology has received a great interest due to its important roles in recent communication and sensor applications. The systems designed for UWB communications transmit data over a wide spectrum of frequency bands with a very low power at very high rates. Ever since the release of unlicensed basis on UWB devices (range of 3.1–10.6 GHz), several works have been carried out to ensure the technology performance. A band-pass filter (BPF) is a key component in the development of UWB systems. The former filter is designed in such a way that signal bandwidth (BW) is around 500 MHz or a fractional bandwidth (FBW) larger than 20 percent at all times of transmission. Designing an UWB-BPF is mostly based in improving filter performance and overcoming some narrowband shortcomings. Different techniques have been used to develop these types of UWB filters. Lumped-element filter design is generally unpopular because of the difficulty of its use at microwave frequencies along with the limitations of lumped-element values. The design of an UWB-BPF with compact size, low insertion loss and wide rejection-band is a challenging task. Introducing defected ground structure (DGS) technique is one of the key to achieve the best performances [1]-[4].

A DGS is an etched periodic or non-periodic cascaded configuration defect in ground of a planar transmission line (e.g., microstrip, coplanar and conductor backed coplanar wave guide) which disturbs the shield current distribution in the ground plane. This disturbance will change characteristics of the transmission line such as line capacitance and inductance [2]-[6]. A number of works have been made so far to make up a variety of planar UWB BPF, in which, the MMR-based UWB BPF is initiated in [7]. Recently, a series of MMR-based UWB BPF have been studied [7]-[9]. This design has the advantages of compact structure, small size, and excellent characteristic in the pass-band, but the attenuation in the stop-band is dissatisfactory.

In this paper, a simple microstrip UWB-BPF using two symmetrical multiple-mode resonators (MMRs) along with a rectangular shaped DGS is investigated. The basic idea and the filter topology are introduced. This design not only improves the harmonic-suppression characteristic in high-frequency stop-band but also reduces the size of MMR. Combining this structure, a rectangular shaped DGS unit is etched on the back of the filter. The simulated results are compared with the measured ones reported elsewhere. The proposed UWB-BPF presents good performance in terms of insertion loss, return loss, fractional bandwidth and compact size than those reported in the literature. The filter will have great potential applications in UWB microwave circuits and systems.

2. Filter Design

The schematic configuration of the proposed UWB-BPF is shown in Fig. 1. The filter consists of parallel coupled feed lines and coupling gaps on the top and a rectangular shaped etched in the ground plane. It is designed on a substrate with a relative dielectric constant of 10.8 and a thickness of 1.27 mm. The use of parallel coupled feed lines is able to enhance the coupling degree between the feed lines. This coupling can be adjusted to control the bandwidth. Accordingly, the symmetrical parallel coupled feed lines can work together to keep the UWB-BPF in the desired range. Several techniques have been used for designing filters to cover the desired range of UWB System [2]-[4], [10]-[18]. The input and output ports are designed to Z_0 of 50 Ω .

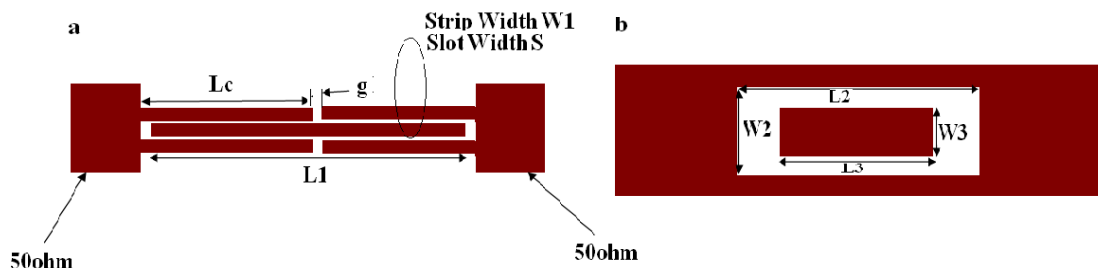


Fig. 1. The proposed UWB-BPF (a) Top view ; (b) Bottom view.

3. Simulated Results

3.1. The effect of the dimensions on the filter performances

In order to investigate the effect of the dimensions on the filter performances, the proposed filter is simulated with different physical lengths L_1 , L_c , L_2 , L_3 and widths W_1 , W_2 , W_3 , S , g . First, the length L_1 is set successively to 4 mm, 7 mm, 8 mm, and 8.24 mm while the other dimensions are kept constant ($W_1=0.1$ mm, $W_2=2$ mm, $W_3=0.4$ mm, $L_c=4.143$ mm, $L_2=4$ mm, $L_3=2$ mm, $S=0.05$ mm, $g=0.134$ mm). The simulated S-parameters are plotted in Fig. 2. It is observed, from Fig. 2, that by decreasing the length L_1 , the bandwidth of the filter is affected significantly. When L_1 is equal to 8 mm, the filter exhibits an ultra-wide bandwidth from 3.1 to 10.6 GHz and an insertion loss less than 0.2 dB.

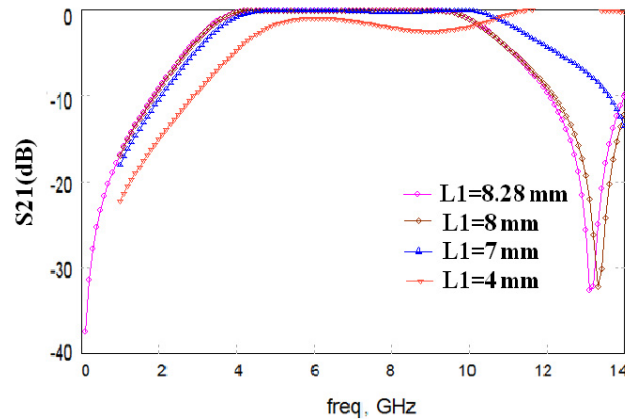


Fig. 2. Magnitude of S_{21} (dB) of the proposed UWB-BPF for different L_1

Fig. 3 shows the simulated S-parameters when W_1 is varied whereas the other dimensions are kept constant ($W_2=2$ mm, $W_3=0.4$ mm, $L_c=4.143$ mm, $L_1=8$, $L_2=4$ mm, $L_3=2$ mm, $S=0.05$ mm, $g=0.134$ mm). As the width W_1 increases the bandwidth decreases. For $W_1=0.1$ mm, the filter exhibits an ultra-wide bandwidth from 3.1 to 10.6 GHz and insertion loss less than 0.2 dB.

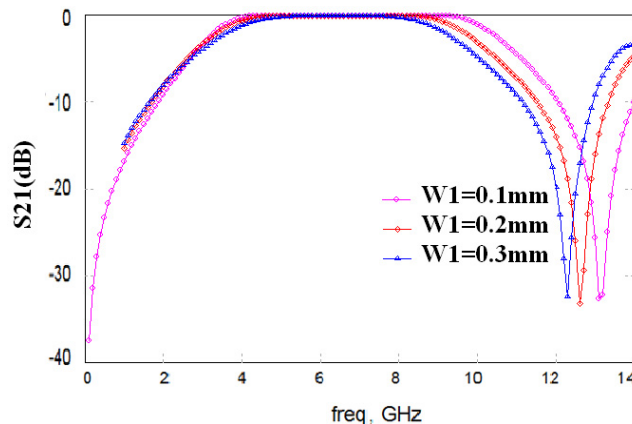


Fig. 3. Magnitude of S_{21} of the proposed UWB-BPF for different W_1

Now, the width S is set consecutively to 0.05 mm, 0.1 mm, 0.15 mm, and 2 mm while the other parameters are kept constant ($W_1=0.1$ mm, $W_2=2$ mm, $W_3=0.4$ mm, $L_c=4.143$ mm, $L_1=8$, $L_2=4$ mm, $L_3=2$ mm, $g=0.134$ mm).

The simulated S-parameters are plotted in Fig. 4. It can be seen from Fig. 4 that by increasing the width S, the bandwidth of the filter decreases. When S is equal to 0.05 mm, the filter exhibits an ultra-wide bandwidth from 3.1 to 10.6 GHz and an insertion loss less than 0.2 dB. Roughly, all dimensions have a great effect on the characteristics of the proposed UWB-BPF. Detailed studies of the effect of the other parameters are lengthy and are not included in this paper.

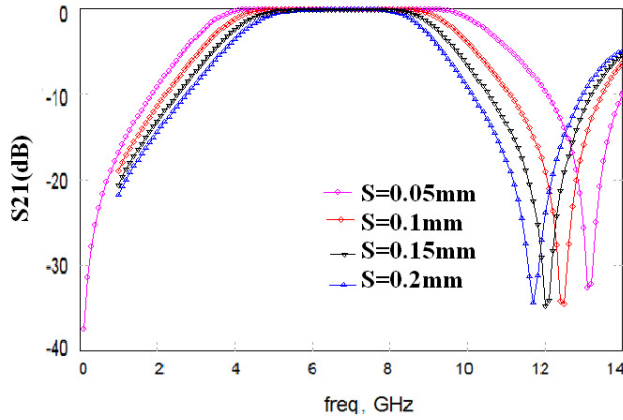


Fig. 4. Magnitude of S_{21} of the proposed UWB-BPF for different S

3.2. DGS Simulation

The simulation result of the DGS, shown in Fig. 1. b, is depicted in Fig. 5.

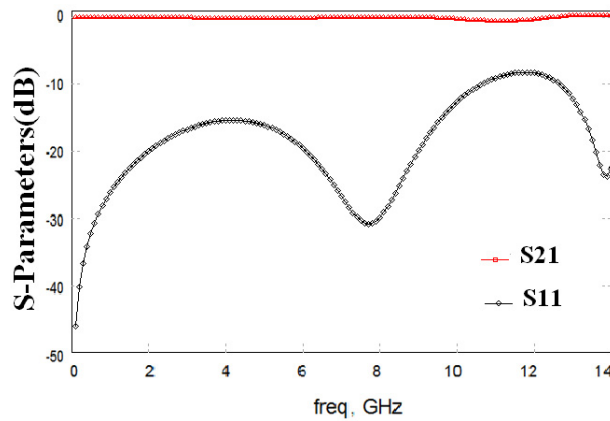


Fig. 5. Magnitude of S_{21} and S_{11} of DGS unit

It is clearly that the return loss is lower than 10 dB and the insertion loss is around 0 dB, so this wide response provides good performance of UWB filter.

3.3. Simulation of Filter without DGS unit

In this subsection, the filter without adding a DGS unit, as shown in Fig. 1. a, is simulated. The filter simulation

is shown in Fig. 6. From this figure, one can observe that the insertion loss is higher than 0.45 dB and the return loss is lower than 10.63 dB. This structure occupies a bandwidth from 3.2 GHz to 10.7 GHz.

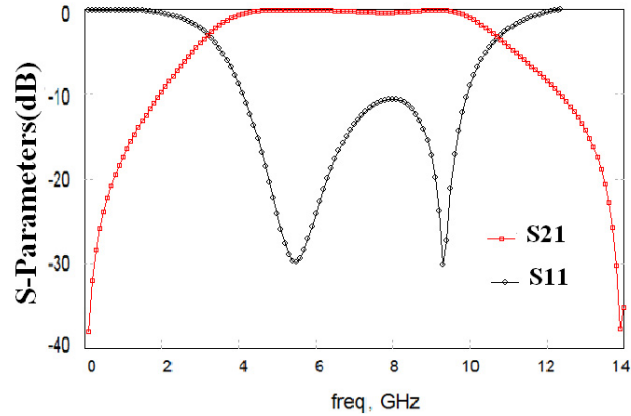


Fig. 6. Magnitude of S_{21} and S_{11} of the proposed UWB-BPF Without DGS

After a thorough parametric study of the filter, the optimum design parameters of the proposed UWB-BPF are listed in Table 1. The simulated frequency response of the proposed filter, illustrated in Fig. 7, shows an obvious UWB bandpass response with a wide passband range of 7.5 GHz, a low insertion loss of 0.2 dB and a return loss higher than 17 dB.

Table 1. Physical Parameters of the Proposed UWB-BPF Structure

Parameters	Dimensions [mm]
W1	0.1
W2	2
W3	0.4
S	0.05
g	0.134
Lc	4.143
L1	8
L2	4
L3	2

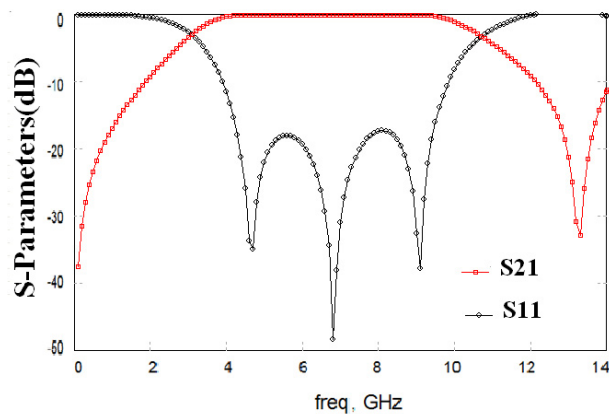


Fig. 7. Magnitude of S_{21} and S_{11} of the proposed UWB-BPF

Figs. 8(a-c), show the current distributions of the UWB-BPF at central frequency f_0 of 6.85 GHz and at stopband frequencies 0.4 GHz and 13.1 GHz. As can be seen, the current density is concentrated at parallel coupled feed lines where the etched DGS units are placed. However, at stopband, the current density is mainly concentrated at the left part of the structure so no passage of current at this frequencies. Disturbs shielding fields on the ground plane, fabrication is a challenging task of the DGS technique.

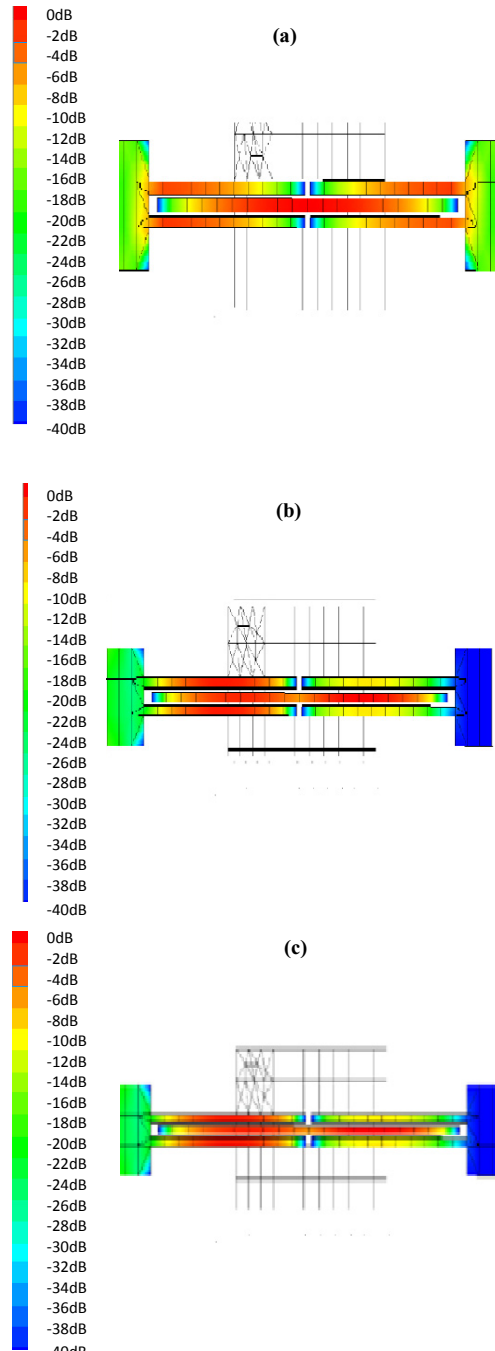


Fig. 8. Current distributions (a) at 6.85 GHz; (b) at 0.4 GHz; (c) at 13.1 GHz

For comparison, the performances of the proposed UWB-BPF are summarized in Table 2 with other filters. It can be seen from Table 2. That the proposed filter provides good performances in stopband rejection, insertion loss, return loss and more compact size ($10.42 \times 2 \text{ mm}^2$) than those reported in literature [16]-[18].

Table 2. Performance Comparison of Microstrip UWB-BPFS

Ref	IL(dB)	RL(dB)	BW (GHz)	Stopban(GHz) rejection	Size (mm ²)
[16]	< 2	> 10	7.5	2.7–13	6.2x2.7
[17]	0.46	10	9	2.1–12.8	12x15
[18]	< 1.6	> 13	9	2.5–11.5	16x1.08
This work	< 0.2	> 17	7.5	1.2–2.75	10.42 x 2

4. Conclusion

In this paper, an UWB-BPF using DGS technique has been successfully developed. The proposed filter has been validated by simulation and, the obtained results have been successfully compared with the experimentation of different types of filters reported in literature. The proposed filter has the advantages of low insertion loss of 0.2 dB, return loss higher than 17 dB, stopband with -15 dB rejection from 1.2 GHz to 12.75 GHz and compact size of $10.42 \times 2 \text{ mm}^2$. Furthermore, the filter has a simple structure. This filter could be widely used for UWB microwave applications.

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