LETTER

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A broadband bandpass filter using triple-mode defected ground structure resonator

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Abstract: A broadband bandpass filter with a dual-plane structure is proposed. The dual-plane structure consists of a pair of L shaped microstrip feed lines on the top layer and a triple-mode defected ground structure resonator (TMDGSR) on the bottom layer. Electric field distributions and frequency response of the TMDGSR are investigated. A sample filter using TMDGSR with a 31.9% of 3-dB relative bandwidth at the centre frequency of 3.6 GHz is fabricated and measured. The simulation and measurement results show that the TMDGSR has some advantages such as: simple compact triple-mode resonator structure and broadside coupling with feed lines easily, which are very useful in broadband DGS BPFs design.

Keywords: tri-mode resonator, defected ground structure resonator, band-pass filter

Classification: Microwave and millimeter-wave devices, circuits, and modules

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1 Introduction

With the rapid development of modern wireless communication system, filters with features of small size, low insertion loss and wide bandwidth are highly desired. Since bandpass filters (BPFs) based on multimode resonator have many superior features, such as compact size and wide passband [1, 2] etc. Multimode resonator BPFs have become an active topic in recent years. A popular way to design multimode resonator filters is using stubs loaded microstrip resonators. In [2], open-ended stubs centrally loaded resonator is presented to design a dual mode wideband bandpass filter with 45% 3 dB relative bandwidth. In [3], a dual mode filter with 13% relative bandwidth is achieved by using short-ended stub. In [4], a triple band BPF is realized by using more identical open-ended stubs, which are connected to a half wavelength resonator symmetrically. The BPF operating at the center frequencies of 1.61 GHz, 3.54 GHz and 5.82 GHz is able to achieve the relative bandwidths of 5%, 14.0% and 3.2% respectively. Other skills to implement multi-mode resonators filters are using defected ground structure. In [5], defected ground spiral resonator is used to design a dual-band filter with relative bandwidth 4.5%, 3.3% at 1.87 GHz and 2.43 GHz respectively. In [6], three nested dual-mode defected ground structure resonators are used to implement a tri-band filter with relative bandwidth 6.6%, 4.4% and 3.8% at 1.59/1.82/2.44 GHz. In [7], defected ground waveguide is applied to design dual-band filter with relative bandwidth 7.5%, 6.4% at 3.6/5.3 GHz. In [8], a four mode defected ground structure resonator (DGSR) is presented to design dual band filter with relative bandwidth 12.8%, 1.47% at 2.58 GHz and 5.86 GHz respectively. The bandpass filter with the center frequency of 3.6 GHz and a 560 MHz 3 dB bandwidth is achieved by using open-loop defect ground waveguide in [9].

Compared with most of the stubs loaded multimode resonator BPFs, the relative bandwidth of the DGSR BPFs needs to be improved. To design broadband defected ground multimode resonator BPFs, it is necessary to develop novel defected ground structure.

In this letter, a broadband dual-plane BPF using novel TMDGSR is presented. The structure consists of a pair of L shaped microstrip feed lines on the top layer and a TMDGSR on the bottom layer. Electric field distributions and frequency response of the TMDGSR are then investigated. Finally a sample of the proposed filter operating at 3.6 GHz with 3-dB relative bandwidth of 31.9% is fabricated and

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measured. The simulation and measurement results show that the TMDGSR has some advantages such as: simple compact triple-mode resonator structure and broadside coupling with feed lines easily, which are very useful in broadband DGS BPFs design.

2 Analysis of the TMDGSR

The structure of proposed filter is shown in Fig. 1(a). The dual-plane bandpass filter is realized by etching a TMDGSR on the ground plane, and a pair of L shaped microstrip lines as I/O feed lines on the top layer. Obviously, the filter is symmetrical with respect to plane AB. By vertically broadside overlapping circuits on different layers, tight coupling is easily achieved between the feed lines and the compact TMDGSR. Dimensional parameters of bottom layer and top layer are given in Fig. 1(b) and Fig. 1(c).

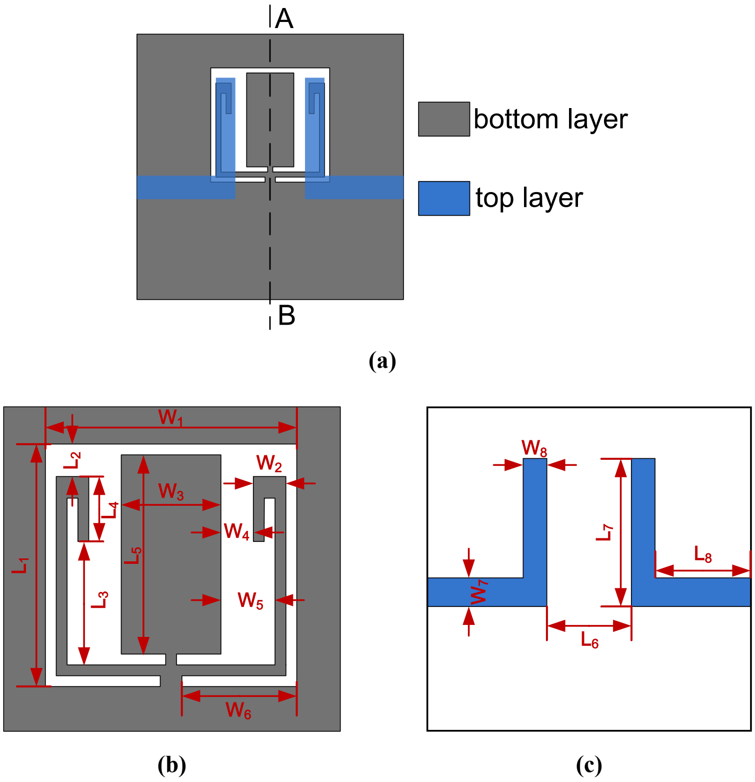

Fig. 1. (a) Scheme of the proposed filter. (b) Layout of the bottom layer. (c) Layout of the top layer

ANSYS Electronics Desktop is used to analyse the eigenmode properties of the TMDGSR. The electric field distributions of the TMDGSR are plotted in Fig. 2. From the electric field distributions around plane AB, especially in area A (see solid line circle in Fig. 2), the distributions of electric field in Fig. 2(a) and Fig. 2(c) are even mode, and the distribution of electric field in Fig. 2(b) is odd mode. Besides, it also implies that tuning L_5 is able to significantly shift even mode resonant frequencies although the impact on odd mode resonant frequency is negligible. Furthermore, it is noticed that electric field distribution in area B (see the dash line circle in Fig. 2) of even mode I is weaker than that of odd mode

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and even mode II, so adjusting L_4 can change the resonant frequencies of odd mode and even mode II together significantly with negligible effect on resonant frequency of even mode I. High density electric field are distributed along the left side and right side of the TMDGSR, so I/O feed lines on top layer are supposed to cover these region to achieve favorable coupling.

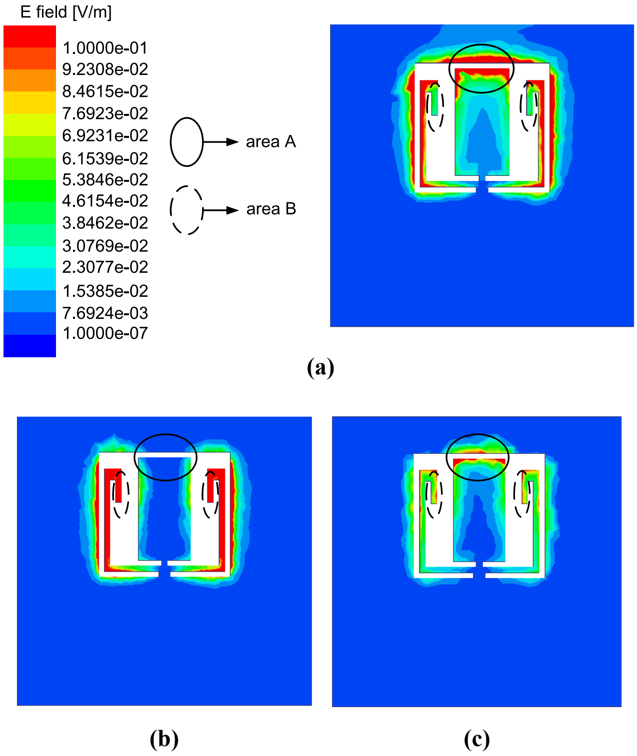

Fig. 2. Electric field distributions of the DGSR. (a) Even mode I at 3.2 GHz. (b) Odd mode at 4.0 GHz. (c) Even mode II at 4.3 GHz

To testify the analysis above, weak coupling excitation is adopted to investigate the frequency response of the tri-mode DGSR.

Fig. 3 shows the frequency response under different L_5. It is noted in Fig. 3 that even-mode I resonant frequency f_{e1} and even-mode II resonant frequency f_{e2} increases as L_5 decreases, while odd-mode resonant frequency f_o remain the same.

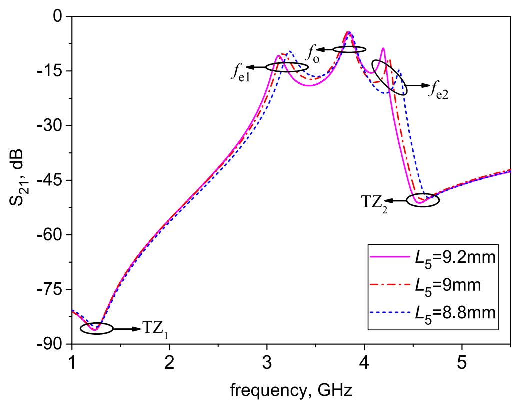

Fig. 3. Simulated results of S_{21} under weak coupling with different L_5

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Frequency response under different L_4 are plotted in Fig. 4. It is clear in Fig. 4 that the larger the length of L_4, the lower the frequencies of f_{e2} and f_o, meanwhile f_{e1} is nearly fixed.

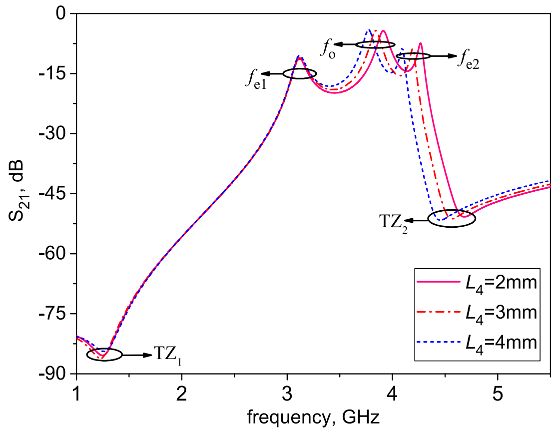

Fig. 4. Simulated results of S_{21} under weak coupling with different L_4

3 Filter design and measurement

The proposed TMDGSR is applied to design a broadband BPF with the center frequency of 3.6 GHz, 32% of the 3 dB relative bandwidth, and a 20 dB return loss. To improve the stopband suppression performance, two transmission zeros are designed on both sides of the center frequency. Comprehensive utilization the filter synthesis and optimization skills [10], a coarse triple-mode broadband BPF model is constructed. The possible coupling matrix is

$$[M] = \begin{bmatrix} 0 & 0.3764 & -0.6843 & 0.4359 & 0.0872 \\ 0.3764 & -0.6614 & 0 & -0.4274 & 0.3764 \\ -0.6843 & 0 & 0.60000 & 0 & 0.6843 \\ 0.4359 & -0.4274 & 0 & 1.2100 & 0.4359 \\ 0.0872 & 0.3764 & 0.6843 & 0.4359 & 0 \end{bmatrix}$$

For the purpose of effectively exciting triple modes, a pair of L shaped I/O feed lines mainly covering the high density region of the electric field are introduced. Eventually, a bandpass filter is fabricated on the substrate with relative dielectric parameter of 2.2, substrate thickness of 0.76 mm and conductor thickness of 0.035 mm. The dimensions of the filter after optimizing are given as follows (unit: mm):

$W_1 = 11.8$, $W_2 = 1.5$, $W_3 = 4.6$, $W_4 = 2.5$, $W_5 = 2.5$, $W_6 = 5.3$, $W_7 = 2.3$, $W_8 = 1.9$, $L_1 = 11.2$, $L_2 = 1.5$, $L_3 = 5.7$, $L_4 = 3$, $L_5 = 9.2$, $L_6 = 6.8$, $L_7 = 11.9$, $L_8 = 7.7$.

Photograph of the fabricated broadband BPF filter is shown in Fig. 5. The simulated and measured dB[S(2,1)] and dB[S(1,1)] are plotted in Fig. 6. The results show that the center frequency of the fabricated filter is 3.6 GHz and the 3 dB relative bandwidth is 31.9%. The return loss is lower than −17 dB and the insertion loss is −0.88 dB. There are two transmission zeros located at 1.47 GHz and 4.83 GHz, which help to improve performance of the stopband suppression superior to −40 dB.

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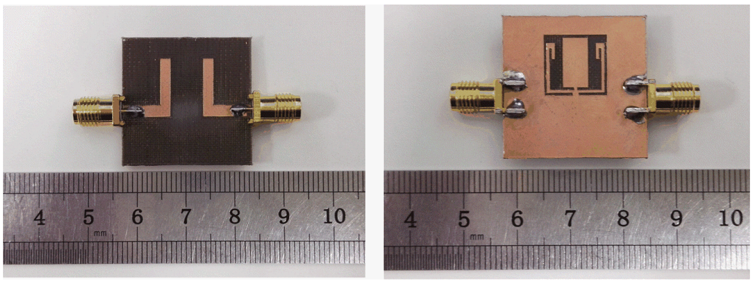

Fig. 5. Photograph of the fabricated filter

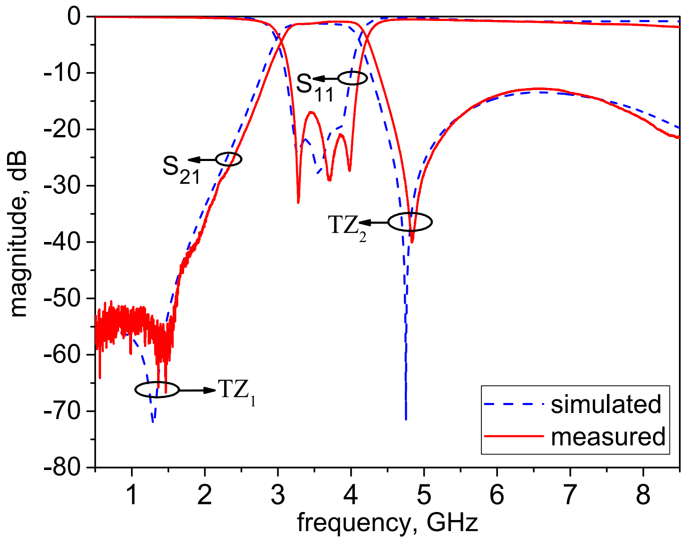

Fig. 6. Simulated and measured results of the filter

4 Conclusion

A broadband bandpass filter using TMDGSR is proposed. The dual-plane structure filter consists of a pair of L shaped microstrip feed lines on the top layer and the proposed TMDGSR on the bottom layer. By vertically broadside overlapping circuits on different layers, tight coupling is easily achieved between the feed lines and the compact TMDGSR. The simulation and measurement results show that the TMDGSR has some advantages such as: simple compact triple-mode resonator structure and broadside coupling with feed lines easily, which are very useful in broadband DGS BPFs design.

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