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# A compact bandpass filter by use of defected ground structures

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**Abstract:** In this paper, a novel technique to design bandpass filter, is presented. Defected Ground Structures (DGS) are used as the main block of the filter. Two filters with different center frequencies and fractional bandwidths with two different structures have been simulated designed and compared. By changing the dimensions of the structure, filter response can be easily controlled. Several useful graphs have been presented to design other filters. Three sections of DGS have been cascaded which improve the response of the filter.

**Keywords:** bandpass filter, defected ground structure, microstrip
**Classification:** Microwave and millimeter wave devices, circuits, and systems

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## 1 Introduction

Microstrip lowpass or bandpass filters are critical parts in microwave circuits in order to suppress harmonics and out of band noise of amplifiers, antennas, and oscillators. Also bandpass filters with wide bandwidth are more important in ultra wideband systems and transceivers. Parallel coupled microstrip filters and stepped impedance resonators are very well known and easy structures for microwave filters. But these structures occupy large size and have spurious response at twice of the center frequency ($2f_0$) [1].

A good alternative to solve the drawback of above-mentioned filter is defected ground structures (DGS) as a kind of electromagnetic bandgap structures (EBG). Defected ground structures are realized by etching a pattern from the metallic ground of a microstrip line [2]. Several patterns have been introduced in literature to design DGS resonators such as dumbbell, square or spiral shaped [3].

The pattern cut in the ground plane, disturbs the current distribution, and changes the characteristics of line such as its inductance and capacitance. The defected slot has bandgap properties at some frequencies which have lots of application in many microwave structures to suppress harmonics of power divider [4] or coupled line filters [5].

However, in this paper, we attempt to use DGS resonators to design a compact bandpass filter directly, in which the DGS resonators are used as the main block of the filter. To simplify the design procedure, some useful design graphs have been extracted.

The article is organized as followed: In section 2, based on [6] a bandpass filter is demonstrated. Several useful design graphs are determined to design filters with desired specifications. To design DGS bandpass filter for higher frequencies, a novel DGS resonator is presented in section 3. The characteristic of the filter is shown to be improved in section 4 using three DGS sections. Some conclusion remarks are presented in section 5.

## 2 Characteristics of a DGS cell

A schematic view of the DGS resonator with face-to-face coupling is demonstrated in Fig. 1 (a) [6]. In most of papers the DGS is excited using microstrip lines at sizes come from conventional design equations. But it can be shown that by etching DGS resonators, radiation occurs from the etched ground plane. So the effective dielectric constant, $\varepsilon_{re}$ of the microstrip structure and its impedance will be increased and to realize a microstrip line with characteristic impedance of 50 Ω, the exciting microstrip line width should be greater than the width of conventional microstrip line. The suggested exciting structure is shown in Fig. 1 (b). The narrower line width is equal to a 50 Ω microstrip line.

Based on this structure, a DGS bandpass filter has been designed. Dielectric constant, loss tangent, and thickness of the substrate are equal to 10, 0.0019, and 0.635 mm respectively. Dimensions of the structure are as


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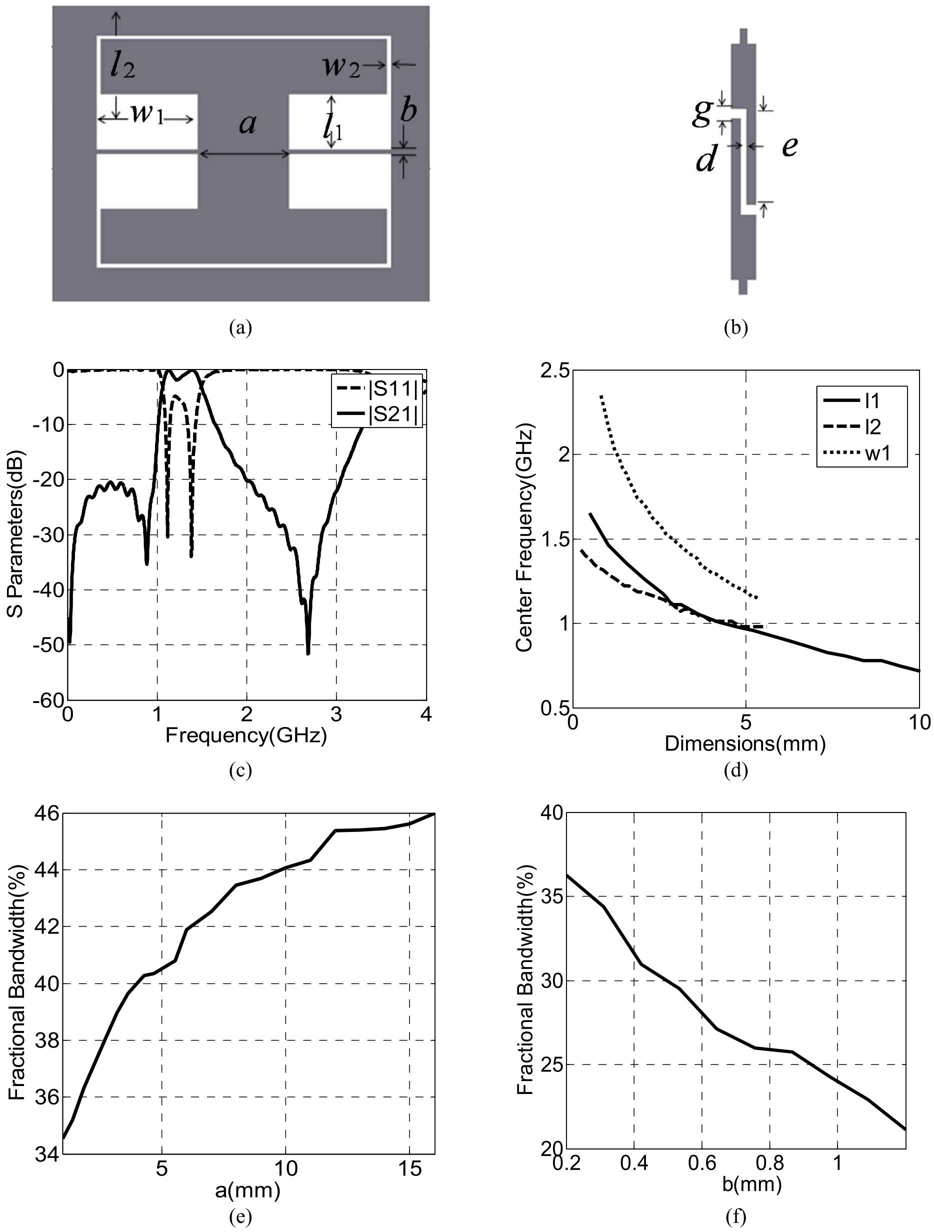


**Fig. 1.** (a) Schematic view of the ground plane of DGS microsrip bandpass filter (black sections are metallic) (b) microstrip line (c) simulated frequency response (d), (e) and (f) variations of filter specifications versus to dimensions.

followed (unit: mm):

$$l_1 = 2.7,\ l_2 = 2.6,\ w_1 = 5.2,\ w_2 = 0.22,\ a = 3,\ b = 0.3,\ w_p = 2.6,\ w_l = 2.4$$
$$e = 1.8,\ d = 0.25,\ g = 0.4$$

The simulated response of the structure is plotted in Fig. 1 (c), which has been obtained from CST-EM Simulator. The center frequency of the filter is 1.25 GHz and its fractional bandwidth is 34%. Two poles can be seen in the response due to the coupling of two sections of the resonator.

Center frequency of the filter can be controlled easily, by changing the dimensions of the structure. Some useful graphs are computed and shown


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in Fig. 1 (d), (e) and (f). In all cases, by varying one parameter, the other parameters are kept constant according to the above dimensions. Fig. 1 (d) shows that by increasing '$l_1$', '$l_2$' and '$W_1$', center frequency of the filter will be decreased. The variation of the center frequency with 'a' and 'b', has been studied, too. And the center frequency was constant. But fractional bandwidth has been changed. This variation has been demonstrated in Fig. 1 (e) and (f). According to Fig. 1 (f), by increasing the spacing 'b', the fractional bandwidth will be decreased however by decreasing the spacing 'a', the fractional bandwidth will be increased, which has been demonstrated in Fig. 1 (e). So to design a filter with given center frequency and fractional

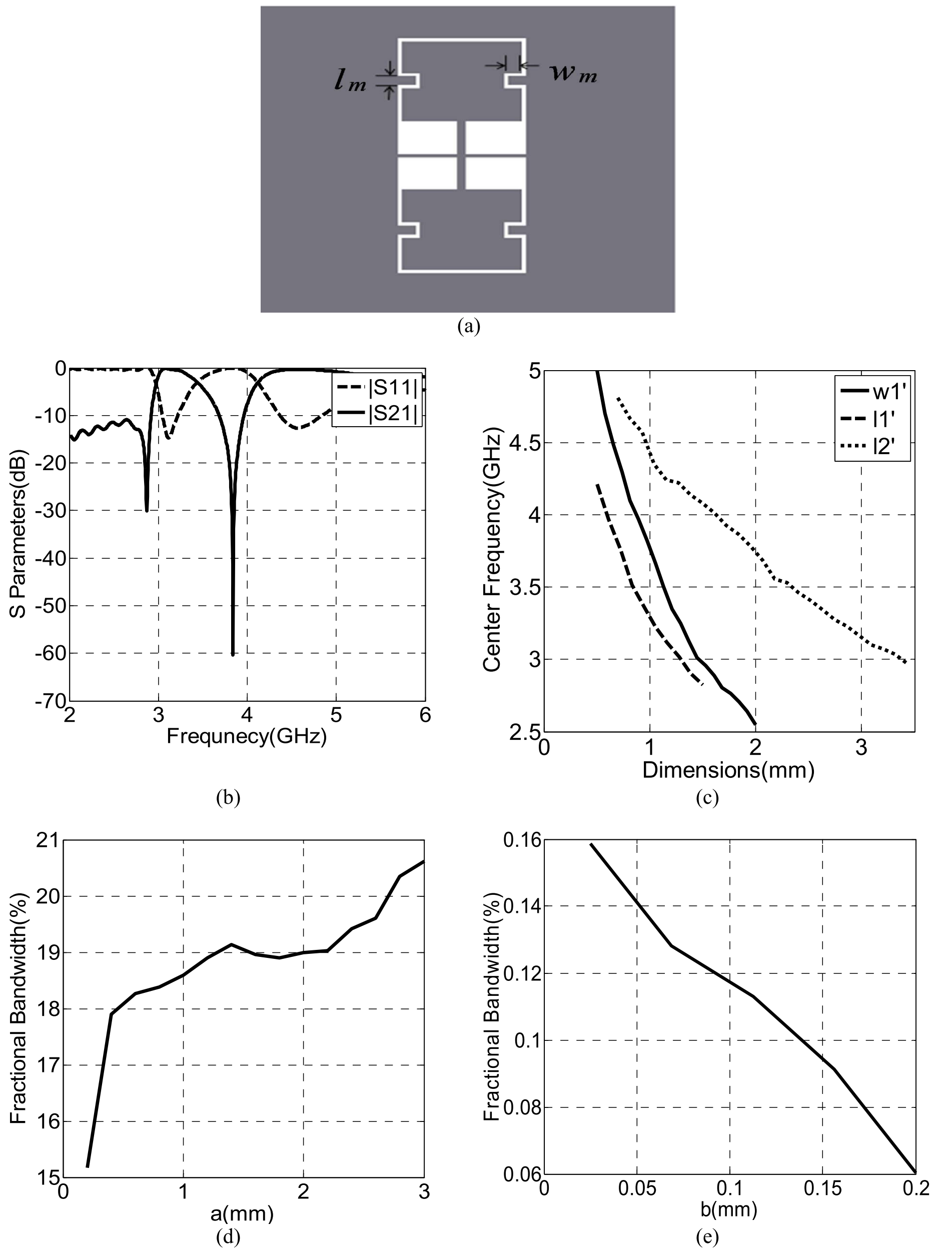


**Fig. 2.** (a) Schematic view of the ground plane of the proposed DGS bandpass filter (b) simulated frequency response (c), (d) and (e) variation of filter specifications versus to dimensions.


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bandwidth, these diagrams will be useful.

## 3 A novel DGS cell for higher frequency bandpass filter

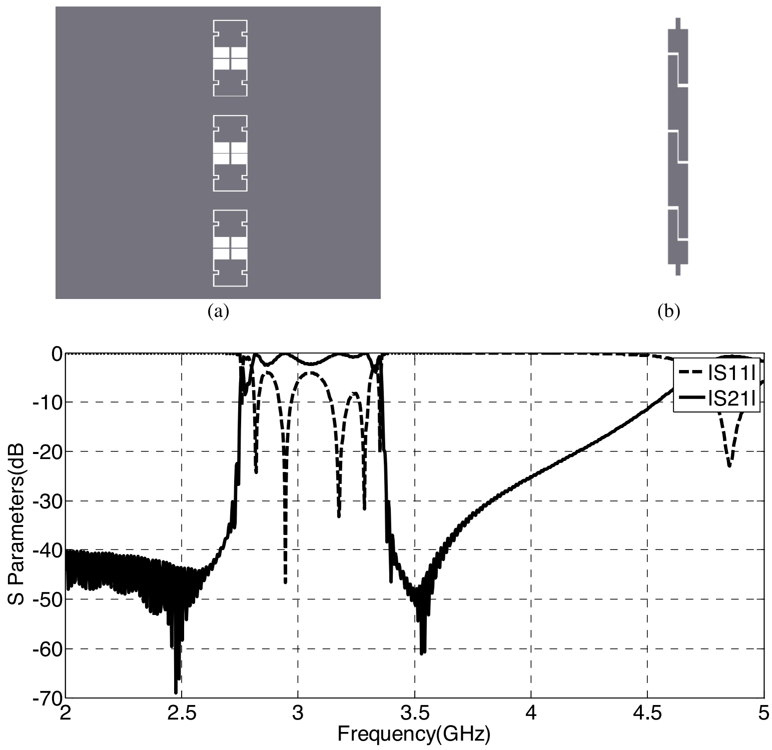
Obviously, higher frequencies require smaller sizes, which restrict to implement the above structure for higher than 1.4 GHz approximately. It can be seen that, to design filter, by means of this structure for higher frequencies, the dimensions of the structure should be shortened which the construction of such structure is difficult or may be impossible (especially for the spacing of 'b'). Therefore, a novel structure has been plotted on Fig. 2 (a). The meander sections increase the current path and compensate increase in spacing.

To demonstrate the effectiveness of this structure, it has been simulated by CST-EM Simulator and the S parameters responses have been plotted in Fig. 2 (b). The dimensions of the structures are as followed (unit: mm) in which prime parameters are corresponded to the parameters in Fig. 1 (a).

$$l'_1=1,\ l'_2=2.8,\ w'_1=0.95,\ w'_2=0.1,\ a'=0.2,\ b'=0.1,\ w_m=0.35,\ l_m=0.35$$

Center frequency and fractional bandwidth of the filter are 3.2 GHz and 14%, respectively.

From several parametric analyses, some other design graphs have been obtained which can be found in Fig. 2 (c), (d) and (e). Similar to the previous structure, by increasing the dimensions of the structure, center frequency




(c)

**Fig. 3.** (a) Schematic view of the ground plane of the proposed microsrip DGS bandpasss filter (b) microstrip line (c) simulated frequency response of the proposed DGS band pass filter.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of the filter will be decreased. But spacing 'a' and 'b' have not significant influence on the center frequency. But fractional bandwidth, will be increased by increasing the spacing 'a' and decreasing spacing 'b'. Therefore, we can control center frequency and fractional bandwidth of the filter by changing dimensions and spacing of the filter, respectively.

## 4 Improvement in filter response

To improve the response of the filter, three sections of DGS cells have been cascaded, in this section. By cascading three DGS cells as same as Fig. 3 (a) and Fig. 3 (b), the response of filter, has been changed greatly. According to Fig. 3 (c) center frequency of the filter is 3.3 GHz and its fractional bandwidth is 20%, which is considerable to the previous structure.

## 5 Conclusion

In this paper a novel approach to design bandpass filter has been presented. DGS cells have been used as the main block of the structure. By changing the dimensions of the structure, the filter specification could be controlled, easily. Useful graphs for the future design have been reported. 3 similar DGS cells have been cascaded, which result in a bandpass filter with wide bandpass and sharp response.


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