

Characteristics of a Novel Slow-Wave Defected Ground Structure for Planar Wideband Filters

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Abstract. This paper presents a new approach for designing compact band stop and band pass filter. This technique is based on defected ground structure. Despite other filters that use DGS just to improve the response of the filter, in this paper Defected Ground Structure is used as the building block of the filter. The center frequency of the filter can be easily controlled by changing the dimension of the DGS resonator. Two filters with center frequency of 1.17GHz and 3.2GHz has been designed and simulated. The structure of the filter has been improved for wideband and high Q applications. Current characteristics and slow wave factor of the filter have been analyzed.

Keywords: Defected Ground Structure, Filter, Microstrip, Wideband, Slow-wave factor.

1. Introduction

Filters with lowpass, bandstop or bandpass are critical components in many microwave and millimetre wave systems. They are used to suppress harmonics and spurious signals of amplifiers and oscillators. An easy way to design a microstrip filter is stepped impedance resonators. But the main problem of such filter is existence of harmonics and this kind of filter has poor power handling. So a new technique should be presented without these problems. Defected Ground Structures as Electromagnetic Band Gap (EBG) is a new effective technique to design low pass and band pass filters or to improve the response of the filters.

In recent years interest on defected ground structures as a kind of electromagnetic band gap structures is growing. DGS is realized by etching of a defected pattern from the backside of metallic ground and has periodic or non-periodic structure. DGS was first proposed in [1] which has a dumbbell shaped. After that lot of DGS structures with various shapes have been proposed. We can mention to square shaped [2], spiral shaped [3] and H-shaped [4].

Defected ground structures disturbs the shielded current distribution in the ground plane and thus change the characteristics of microstrip line such as its inductance and capacitance so they have rejection band in some frequency ranges. Also these structures have slow-wave properties. By proper use of the ground plane these structures reduce the size of microstrip component significantly.

The rejection properties of defected ground microstrip lines are so useful in many microwave circuits for harmonic suppression such as power divider [5], or improvement the response of antennas [6]. However most of the researches are focused on the band rejection properties of these structures and a few papers have been reported that use DGS structures as a building block to realize microwave circuits as bandpass filters.

In this paper, we propose a new bandpass filter which uses DGS as a building block of the structure. The filter consists of a DGS resonator and a microstrip line, with a compact size. The frequency response of the structure can be easily controlled by changing the dimension of the DGS resonator.

This article is organized as followed: In II, based on [7], the bandgap properties of a DGS cell are demonstrated. By changing line properties a bandpass filter is obtained. According to that, a novel DGS filter is proposed that is suitable for higher frequencies. In section III, current properties and slow wave effect of the structure is analysed. Finally a conclusion is reported in section IV.

2. Characteristic of the DGS Cell

Fig. 1(a) shows the schematic diagram of the ground of a DGS, with face to face coupling which was used in [7]. In Fig. 1(b) the line of the filter is demonstrated. The line width should be chosen for the characteristic impedance of 50Ω , but it can be shown that by etching defected ground, effective dielectric constant ϵ_{re} of the microstrip is increased thus the characteristic impedance will be greater than 50Ω . So for matching the microstrip line to the ports, we suggest that the width of the line above the DGS section should be increased, also we should connect two line with characteristic impedance of 50Ω at the two ports of the structure. The substrate with a dielectric constant of 10, loss tangent of 0.0019 and thickness of 0.635 mm is considered. In order to investigate the frequency response of the DGS cell, it is simulated by CST EM-simulator. The dimensions of the structure are tabulated in table I. Dimensions are based on mm.

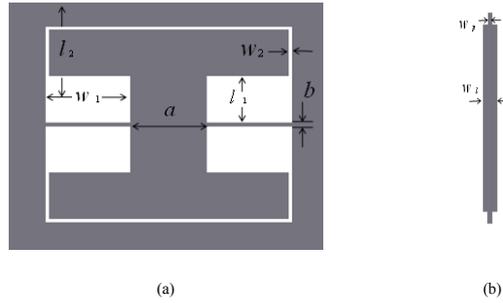


Figure 1. Layout of a band stop filter (a) ground plane using DGS resonators with face to face coupling, (b) microstrip line..

TABLE I. PHYSICAL DIMENSION OF THE STRUCTURE OF DGS BANDSTOP FILTER WITH FACE TO FACE COUPLING (UNIT:MM)

l_1	l_2	w_1	w_2
2.7	2.6	5.2	0.22
a	b	w_p	w_l
3	0.3	0.6	2.4

Fig. 2 illustrates the simulated response of this structure which is of order two and the two equal resonators are coupled together via the line. The band stop response of this structure shows two polls in the bandstop due to the two resonators that are coupled together.

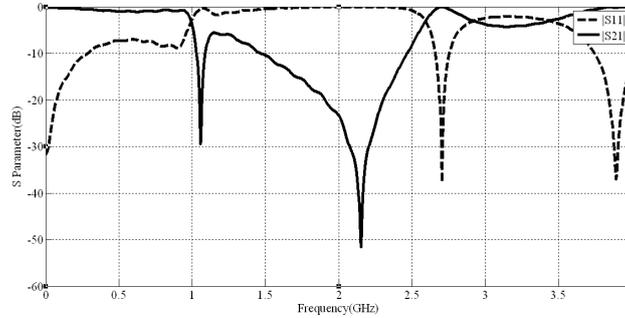


Figure 2. Simulated S-parameters characteristic of the bandstop DGS filter with face to face coupling.

Because of its tight coupling, this structure shows sharper transition compared to the back to back filter investigated in [11].

By etching a gap in the line, the bandstop response of this filter is converted to a bandpass one with the same central frequency. The schematic view of the line with interdigital gap is illustrated in Fig. 3 where $e=1.8\text{mm}$, $d=0.25\text{mm}$ and $g=0.4\text{mm}$.

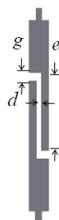


Figure 3. Schematic view of the line with interdigital gap

The simulated response of the filter is shown in Fig. 4 where the central frequency of the filter is 1.17GHz and fractional bandwidth of it, is equal to 35%. The fractional bandwidth of the filter can be calculated from (1), where f_0 , f_1 and f_2 are central frequency, first and second 3dB frequencies, respectively.

$$FBW = f_0 / (f_2 - f_1) \quad (1)$$

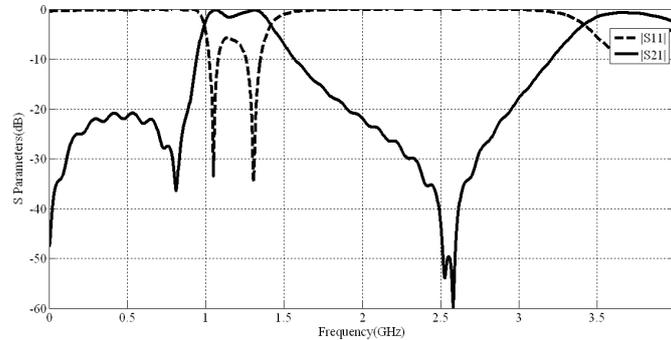


Figure 4. Simulated S parameters characteristic of DGS bandpass filter using line with interdigital gap.

By changing the dimensions of DGS cells, central frequency of the bandpass filter can be changed easily. But the structure mentioned above, interfaces a great problem due to the need to shorten the dimensions of the cell for the second band design and the spacing (w_0) is bounded to a lower limit due to technology restriction.

So, we propose a new DGS cell, with meander section. The meander lines, lead to an increase in the current path, compensating the effects caused by the increase in spacing.

The proposed cell and its response are illustrated in Fig. 5 and Fig. 6, respectively. Central frequency of this bandpass filter is 3.2 GHz. The dimension of the structure is tabulated in table II. So if we have difficulty with the dimension if Fig. 1(a), structure of Fig. 5 can be used alternatively.

TABLE II. PHYSICAL DIMENSIONS OF THE PROPOSED DGS BANDPASS FILTER.

l_1'	l_2'	w_1'	w_2'
1	2.8	0.95	0.1
a'	b'	w_m	l_m
0.2	0.1	0.35	0.35

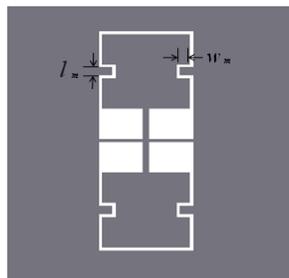


Figure 5. Schematic view of the ground plane of the proposed DGS bandpass filter.

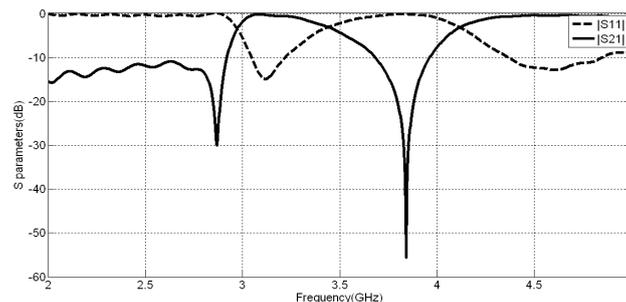


Figure 6. Simulated S parameter characteristic of the proposed DGS band pass filter.

3. Improvement of the Response

In the simulated response of Fig. 4, it can be seen that the stopband rejection is less than 30 dB also we want to improve the sharpness filter. For that, we propose a new structure, which is composed of cascade connection of three cells, with separation of 9.8 mm. The schematic diagram of the structure is illustrated in Fig. 7 and the simulation results are shown in Fig. 8. The stopband rejection is now more than 40 dB and the sharpness of the passband have been improved. The bandwidth of the passband is 51%.

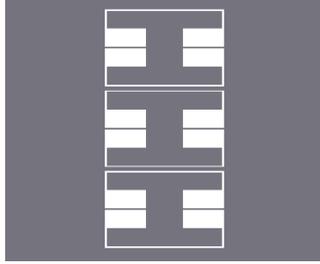


Figure 7. Schematic view of ground plane of the proposed ultra wide band DGS band pass filter with cascaded resonators.

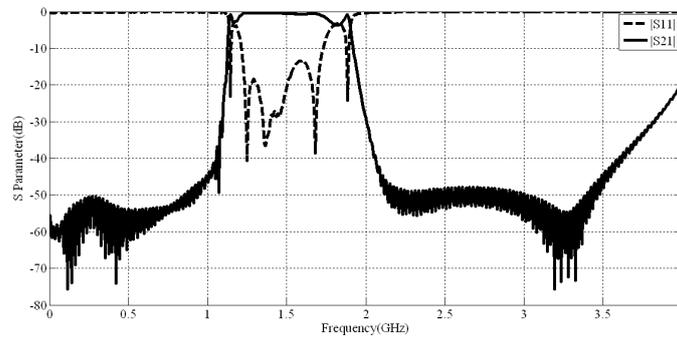


Figure 8. Simulated S parameter characteristic of proposed bandpass filter with cascaded resonators.

4. Surviving Slow-Wave Effect

As mentioned above, defected ground structure resonators disturb the shielded current in the ground plane. Fig.7 shows the current path on the ground plane of fig. 1 with bandpass response. As can be seen, the current initials from the input port, turn around the DGS resonator and exits from the output port.

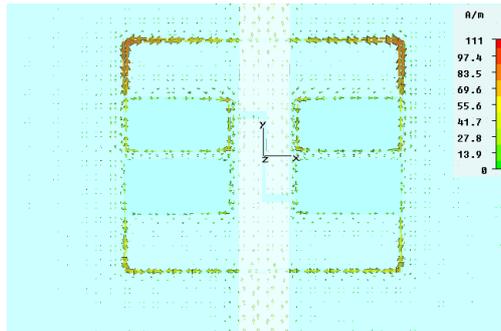


Figure 9. Current path on the ground palane of band pass filter of fig.1 at 1.17GHz.

Also the simulated S parameter shows a resonant frequency in the response of the structure. From that, we can conclude that the DGS structure has slow-wave characteristics and the propagation constant differs from a single microstrip line. To prove this statement, we have computed the slow-wave factor of this structure and compare it with a microstrip line without DGS resonator. The slow-wave factor of a DGS can be computed from (2) and (3), where L is the physical length of the microstrip line, λ_0 is the wavelength in free space, $\Delta\theta$ is the phase difference of microstrip line between with and without DGS and ϵ_{eff} is the effective microstrip permittivity.

$$SWF(f) = \sqrt{\epsilon_{eff,D}} = \lambda_0 \Delta\theta(f) / 360L_p + \sqrt{\epsilon_{eff}} \quad (2)$$

$$\epsilon_{eff} = (\epsilon_r + 1)/2 + (\epsilon_r - 1)/2(1 + 12h/w)^{-0.5} \quad (3)$$

Fig. 8 shows a comparison of the slow-wave factor with and without DGS resonators. It is clear that by use of DGS, the slow-wave factor of DGS is improved.

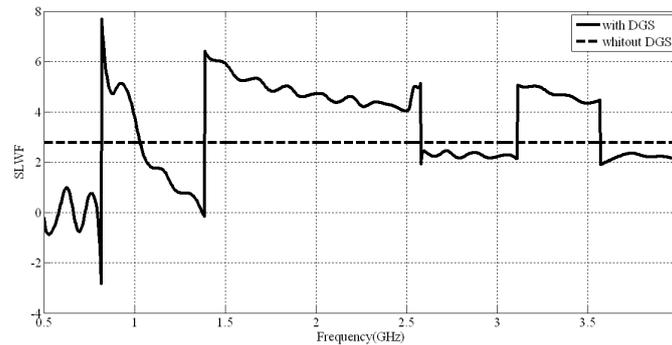


Figure 10. SLWF of DGS

5. Conclusion

In this paper, a novel approach to design bandpass and bandstop filter has been proposed. This technique is based on implementation of defected ground structures as a building block of the filter. By changing the dimension of the filter, frequency response of the filter, can be easily controlled. By cascading three similar resonators, the response of the filter, has been improved greatly. The consequent structure has a wideband response. Surveying of the slow-wave factor of this resonator shows that this factor is greater than a single microstrip line.

6. References

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