Combined DMS and DGS Techniques for Compact and Low Cutoff Frequency LPF Design

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***Abstract*- high performance and compact size low pass filters with narrow stopband and sharp cutoff characteristics are highly required in numerous wireless communication systems for noise and interference suppression. In this paper, a compact microstrip LPF with sharp cutoff characteristics is introduced. Defected ground structure (DGS) and defected microstrip structure (DMS) have been used to obtain wide stopband. The proposed filter is composed of two arc-shaped DGS units in the ground plane and a shaped microstrip line where stub and inset feed matching techniques is attached to enhance the pass band characteristics. This structure allows sharp cutoff frequency response and high harmonics suppression. Furthermore, it provides compact filter size without the need for cascading periodic DGS structures. The stop band attenuation is controlled by adjusting the depth of the inset feed and the length of the stub sections. It has a 3 dB cutoff frequency at 1.3725 GHz and it is as small as 20 mm × 19 mm.**

Keywords: Defected ground structure (DGS), Defected microstrip structure (DMS), arc-shaped, low pass filter (LPF).

1. INTRODUCTION

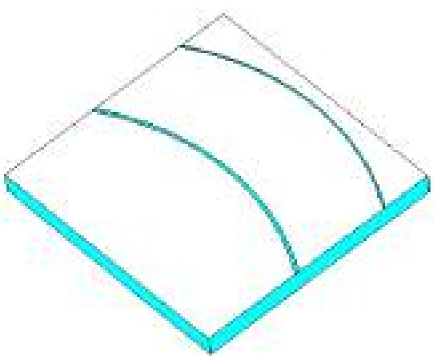
Microwave low pass filters are essential devices in RF wireless communication systems to remove noise, harmonics and other spurious signals. For these circuits, size compactness and high power attenuation levels throughout a broad stopband spectral range are desired properties to efficiently accomplish this task. Different techniques have been investigated i.e. using resonators, shaped transmission lines, and defected ground structures to achieve miniaturization of microwave filter. In [1-3] numerous low pass filters having wide stopband for moderate attenuation levels of about $-15dB$ to $-17dB$ are introduced. But as the attenuation level is increased to -20dB, the widths of the stopband of these filters are reduced. A compact asymmetric shaped microstrip low pass filter (LPF) with ultra wide stopband characteristics was introduced in [4]. The filter is based on Stepped Impedance Resonator (SIR). The asymmetric structure allows the suppressing cell to be located within the resonator structure without occupying a large area. So that the resulting filter occupies only a small area of about $(0.156\,\lambda_g \times 0.128\,\lambda_g)$, where λ_g is the guided wavelength at 2.92 GHz. On the other hand, defected ground structures DGS are widely used to implement compact filters with good passband and stopband characteristics [5,6]. In [6] a compact LPF using double U-shaped DGS units at the ground plane and a shaped microstrip structure DMS on the top was introduced. It provides compact filter size without the need for cascading periodic DGS structures. But, it has relatively high cutoff frequency which equals 2.7 GHz. In [7], a sharp cutoff low pass filter using a tapered resonator has been introduced. But, the manufactured filter has an extensive circuit size. In [8] a compact low pass filter using stepped-impedance hairpin resonator (SIHR), split-ring resonator defected ground structure (ISRR DGS), and elliptical DGSs is introduced. Such structure exhibits low insertion loss and sharp cutoff characteristic. But, it provides high having $3\,dB$ cutoff frequency of $f_c = 2.5\,GHz$. On these lines, an improved Defected Ground Structure using H-slot resonators and coupling matrix method are introduced for compact Low pass /Band pass filters design [9]. The H-slot is used to serve as a DGS cell element for the microstrip line. The DGS component provides size reduction and has capability of harmonics and spurious suppression.

In this paper, an arc-shaped defected ground structure with defected microstrip line is proposed for implementation of compact size, sharp cutoff, and wide stopband low pass filter. Besides DGS and DMS, the inset feed and stub matching technique are utilized to adjust the impedance matching between the feeding port and the transmission line to enhance the input reflection coefficient. The use of this structure allows sharp cutoff frequency response and high stopband attenuation. Furthermore, it provides compact filter size without the need for periodic DGS structures. The proposed LPF is designed using the CST-MICROWAVE STUDIO simulator. The filter is simulated using Rogers's RO4003 substrate of dielectric constant $\varepsilon_r = 3.38$ and thickness $h = 1.524$ mm.

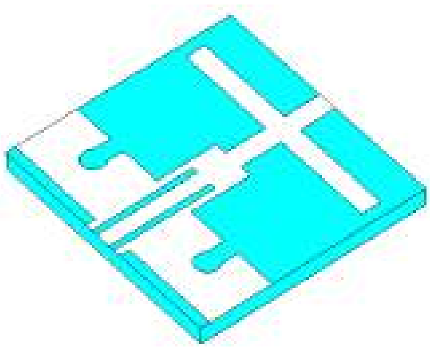
2. PROPOSED FILTER STRUCTURE

In this section, a new design for minimized size low pass filter with relatively flat pass band characteristics and low cutoff frequency is proposed. Keeping in mind the end goal to exhibit the viability of the proposed design, it is utilized for LPF design which is delineated in Figure 1. The designed LPF comprises of two arc-shaped DGS cells with a similar radius however with various widths. The DGS cell is embedded to give high attenuation over a wide stopband. Using the sharp cutoff frequency response of the etched arc-shaped DGS cells and considering the coupling effect between slots in the ground plane can give the required elliptical characteristics of the filter. Likewise, a shaped transmission line is put on the upper surface of the substrate. The transmission line comprises of two segments of various widths where two open circuit twofold stubs are joined. The expansion of these stub segments controls the transmission line impedance which for sure gives a mean to control the attenuation level of the stopband. Besides, to control the input impedance of the transmission line, an inset feed is etched at the input port. The blend between the stub matching and the inset feed techniques provides more opportunity to control the attenuation level in the stopband. The detailed description of the DGS structure and the transmission line is appeared in Figures (2-a) and (2-b) respectively.

The proposed filter has been simulated using the CST-MICROWAVE STUDIO software using Rogers RO4003 substrate of dielectric constant $\varepsilon_r = 3.38$ and thickness $h = 1.524\,mm$ as the same as the double equilateral U-shaped DGS filter presented in [5] and the LPF presented in [6]. The dimensions of both DGS and DMS are listed in table (1).

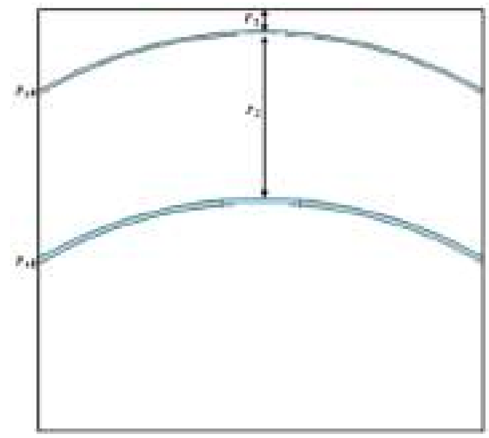


(a)

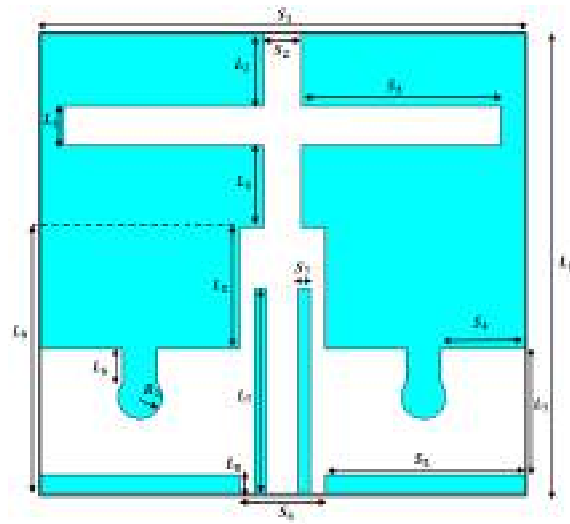


(b)

Fig. 1. (a) Back view and (b) Front view of the simulated CST design of the proposed low pass filter.



(a)



(b)

Fig. 2. Description of the (a) DGS and (b) DMS dimensions.

Table (1). The dimensions of both DGS and DMS

Dimension	Value in mm	Dimension	Value in mm	Dimension	Value in mm
L_1	19	S_1	20	R	20
L_2	3	S_2	1.6	p_3	0.17
L_3	1.6	S_3	8.2	p_4	0.29
L_4	3.4	S_4	3.5		
L_5	5	S_5	8.2		
L_6	1.39	S_6	3.5		
L_7	5.2	S_7	0.5		
L_8	0.8	p_1	1		
L_9	8.5	p_2	7.35		

3. SIMULATION RESULTS

In this section, the simulation results of the proposed arc-shaped DGS low pass filter is compared to both double equilateral U-shaped DGS low pass filter presented in [5] and

LPF presented in [6]. It is worth noting that the three filters are realized on the same Rogers RO4003 substrate with dielectric constant $\varepsilon_r = 3.38$, and thickness $h = 1.524$ mm. Figure 3 shows the scattering parameters $|s_{11}|$ and $|s_{21}|$ of the proposed filter. The filter has low cutoff frequency of $f_c = 1.368\ GHz$. Lowering the cutoff frequency provides much wider stop band which indeed increases the noise and spurious harmonics suppression. The filter stop band extends from $1.368\ GHZ$ to more than $8GHz$ with $|s_{21}| \cong -20dB$. For comparison and showing the effectiveness of the designed filter, it is compared with the low pass filters introduced in [5] and [6] as shown in figure 4. The simulation results showed that the cutoff frequency is lowered from $2.58\ GHz$ and $2.7\ GHz$ to $1.368\ GHz$ that is for the filters presented in [5], [6], and the proposed one respectively. It is clear that the designed filter has sharp cutoff response in comparison to previous work. Besides these, it has a simple design structure.

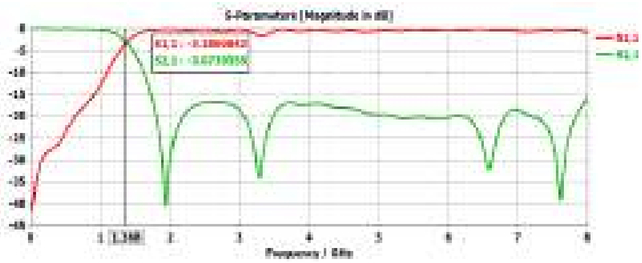


Fig. 3. The simulation results of the proposed low pass filter

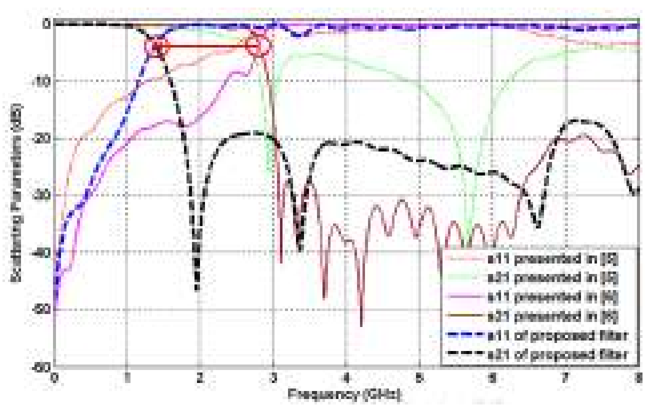


Fig. 4. Comparison between the scattering parameters of the proposed filter and the low pass filters presented in [5] and [6].

4. Conclusion

In this paper, an arc-shaped DGS and DMS are proposed for the execution of compact LPF filter with sharp cutoff frequency response and wide stopband. In addition, inset feed and stub matching techniques are used to adjust the input reflection coefficient of the filter. The proposed filter is realized on Rogers RO4003 substrate with dielectric constant $\varepsilon_r = 3.38$, and thickness $h = 1.524$ mm. The filter stop band extends from $1.368\ GHZ$ to $8GHz$ with $|s_{21}| \cong -20dB$. The simulation results revealed that the designed filter has sharp cutoff response and much lower cutoff frequency in comparison with previous work. Besides these, it has a simple design structure.

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