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Parallel Coupled Bandpass Filter with Improved Filter Characteristics

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Abstract: ***This paper presents parallel-coupled bandpass filter using three rectangular shaped defected ground structure (DGS) with center frequency of 3.2GHz and bandwidth of 187 MHz. The designed filter performs better than the first coupled micro-strip filter [6] by modifying the resonators length, substrate thickness and employing DGS. The prototype filter simulated shows an insertion loss of -0.13 dB and return loss of -35.38 dB centered at 3.2GHz.The designed filter has the benefits of low insertion loss which can be used for modern wireless communications application like WiMAX.***

Keywords: Band-pass filter, defected ground structure (DGS), Micro-strip, resonator, WiMAX

1. Introduction

As communication services are growing, more efficient microwave components are required. Filters are used to eliminate undesired frequencies and isolate the desired frequencies. Filters are classified into four categories in terms of their frequency characteristics: lowpass, highpass, bandstop and bandpass [1–3].The high performance filters are characterised by low insertion loss and high selectivity. In order to realize these high performance filters, DGS is one such technique, which can be used. DGS is formed by etching simple slots on the ground plane, thereby changing the shielded current distribution [4] of the ground plane. The cut-off frequency and attenuation pole frequency is determined by the shape and dimensions of the slot. DGS exhibits both band-stop and slow wave properties due to which, it used in controlling or suppressing the harmonics and as well as size miniaturization. DGS is simple to design and easy to fabricate as compared to PBG/EBG. DGS is not only used to realize compact filters, but also used in the design of power dividers, amplifiers and antennas [5].

In this paper, 3rd order parallel coupled band-pass filter characteristics were improved by increasing the thickness of the substrate ROTMM10 and reducing the resonators length. The performance of the filter was further improved b employing DGS. The designed filter occupies an area of 45.32×10 mm^2.

2. Design

The designed filter has a center frequency of 3.2 GHz, bandwidth of 187 MHz First the coupled micro-strip filter is designed, and then the parametric study on the effect of resonators length on the performance of the filter was carried out using CST.DGS is further added to the designed to improve the return loss factor.

A. Parallel-Coupled Filter Design

Figure 1 shows the filter structure observed in this work. This filter type is known as parallel coupled filter because it is composed of several half wavelength resonators and can be easily designed using ADS, CST, etc.

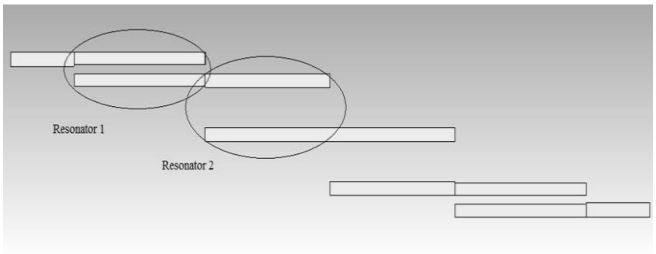

Figure 1: Parallel-coupled band-pass filter

An ideal filter should have zero insertion loss and high attenuation within the stopband. But such filter do not exist is practice. In an image parameter method there is no clear cut way to improve filter parameters; however insertion loss method has higher degree of control over the frequency response of the filter. For example, if flat passband is required, Butterworth response is preferred and for sharp roll off chebyshev response is considered. Considering Butterworth response we can use the following equations for designing the parallel coupled filter:

$$\frac{J_{01}}{Y_0} = \sqrt{\frac{\pi FBW}{2 g_0 g_1}} \quad (1)$$

$$\frac{J_{j,j+1}}{Y_0} = \frac{\pi FBW}{2} \sqrt{\frac{1}{g_j g_{j+1}}} \quad (2)$$

For j=1 to n=1

$$\frac{J_{n,n+1}}{Y_0} = \sqrt{\frac{\pi FBW}{2 g_n g_{n+1}}} \quad (3)$$

Where,

$$\text{FBW} = \frac{\omega_2 - \omega_1}{\omega_0} \quad (4)$$

The values for g_0, g_1,..,$g_n$are often taken from table, FBW is the relative frequency bandwidth, $J_{j,j+1}$ is that the characteristic admittance of J inverter and Y_0 is that the characteristic admittance of the connecting transmission line [6].After calculating the characteristic admittance of the inverter, the next step is to calculate the even and odd mode characteristic impedance using the following equations:

$$(Z_{0e})_{j,j+1} = \frac{1}{Y_0}\left[1+\frac{J_{j,j+1}}{Y_0}+\left(\frac{J_{j,j+1}}{Y_0}\right)^2\right] \quad (5)$$

$$(Z_{0o})_{j,j+1} = \frac{1}{Y_0}\left[1-\frac{J_{j,j+1}}{Y_0}+\left(\frac{J_{j,j+1}}{Y_0}\right)^2\right] \quad (6)$$

Then the distance, width and length of the coupled micro-strip can be calculated using ADS linecalc tool.

3. The Improved BPF

In [6], parallel coupled BPF was simulated on ADS using ROTMM10 substrate of thickness 0.763mm having insertion loss and reflection factor of -2dB and -15dB respectively.

The thickness of the substrate and micro-strip was varied to obtain the superior filter characteristics. It was observed that substrate thickness of 1.6 mm and micro-strip thickness of 0.1 mm gives better result as compared to the results obtained in [6]. To improve the insertion loss factor, the resonator 2 and 3 lengths were reduced from 9.1 to 8.85 mm. The parametric study is performed to see the effect of resonators length on the performance of the filter. Figure 2 and 3 shows the return loss and insertion loss frequency response respectively. From the return loss graph we can observe that the resonator (2 and 3) having lengths 8.85mm gives better insertion loss and return loss results as compared to results obtained in [6].

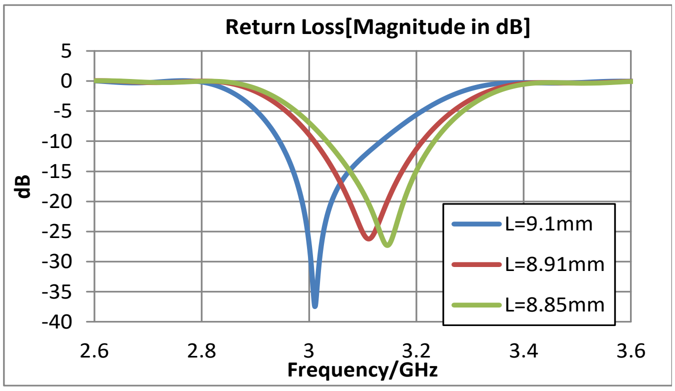

Figure 2: Return loss for different lengths of resonator 2 and 3

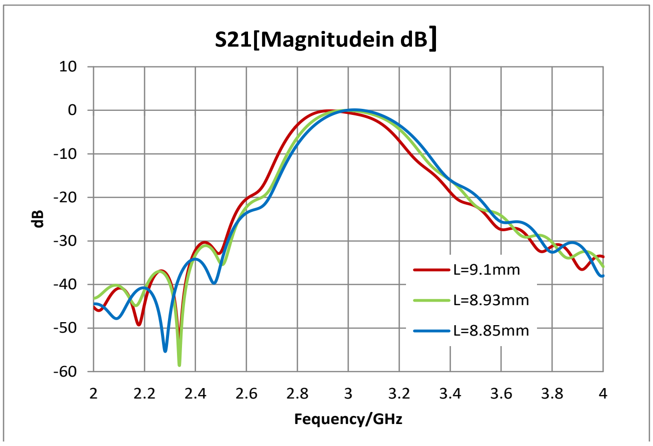

Figure 3: Insertion loss for different lengths of resonator 2 and 3

Due to increase in resonators length the return loss graph has moved away from the center frequency (3.2 GHz).Now for the filter to operate at 3.2 GHz DGS technique is employed. Three rectangular shaped slots were etched in the ground plane as shown in the figure4.

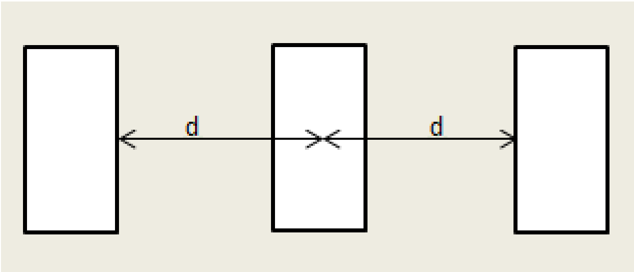

Figure 4: Defected Micro-strip Structure

Figure 5 shows the parametric study performed to see the effect of distance (d) between the DGS slots on the performance of the filter. It was observed that d=8mm gives higher return loss compared to the other dimensions at 3.2 GHz.

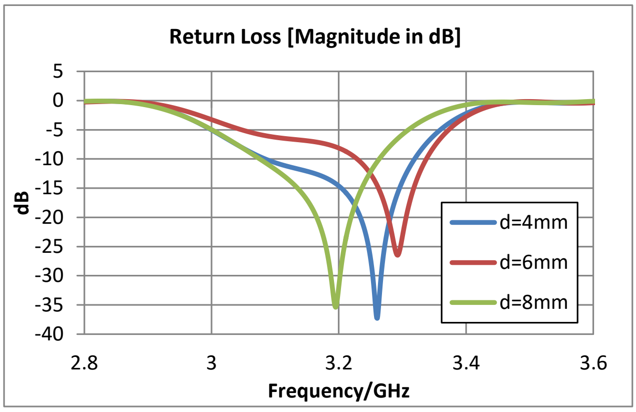

Figure 5: Return loss for different distance (d)

Figure 6 and 7 shows the front view and back view of the improved band-pass filter along with dimensions respectively. The simulated response for the filter is given in figure 8.

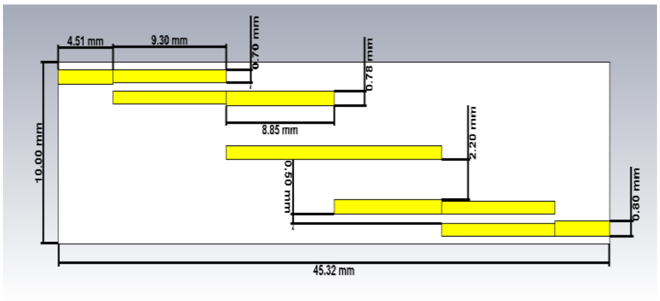

Figure 6: Front view of the proposed filter

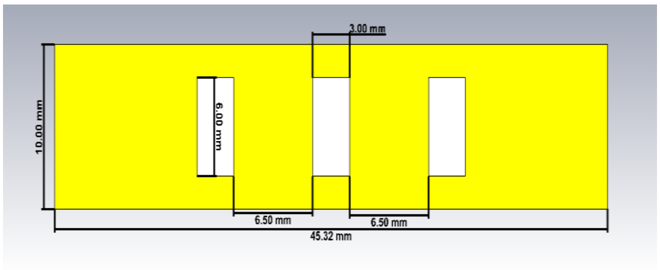

Figure 7: Back view of the proposed filter

4. Result and Discussion

The simulated S_{11} and S_{21} parameters of the 3rd order Butterworth parallel coupled micro-strip band-pass filter is shown in figure 8. From the simulated S_{11} and S_{21} graph, the return loss and insertion loss values at 3.2 GHz are -35.38 dB and -0.13 dB respectively. The obtained low insertion loss and high return loss is ideal for WiMAX applications.

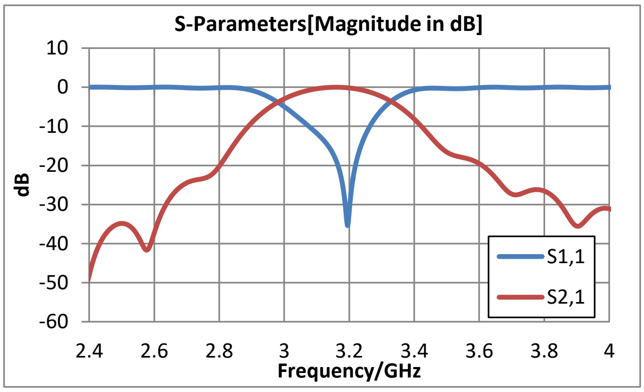

Figure 8: Simulated frequency response of the band-pass filter

Table I shows the comparison of some of the parameters of the improved filter design and reference paper [6].

Table II: Comparison of parameters of the proposed filter and reference paper [6]

Parameters	Ref[6]	This work
Substrate	ROTMM10	ROTMM10
Substrate thickness	0.762mm	1.6mm
Resonator 1 and 4(length)	9.3mm	9.3mm
Resonator 2and 3(length)	9.1mm	8.85mm
Micro-strip thickness	0.763mm	0.1mm
IL(dB)	-2 dB	-0.13 dB
RL(dB)	-15 dB	-35.38 dB
BW(MHz)	50 MHz	187 MHz

Table IIIV shows the simulated results obtained using standard substrate size. It was observed that results obtained using standard substrate thickness of 1.524mm were comparatively better than the standard substrate thickness of 1.270mm. But in this work substrate thickness of 1.6mm gives best results than the other standard substrate thickness available.

Table VVI: Comparison of Simulated Results Obtained Using Standard Substrate Thickness

Parameters	Substrate Thickness		
	1.270mm (standard)	1.524mm (standard)	1.6mm (This work)
Substrate	ROTMM10	ROTMM10	ROTMM10
Distance d	4 mm	8 mm	8 mm
Micro strip	0.070 mm	0.070 mm	0.1mm
IL	-20.57 dB	-23.52 dB	-35.38 dB
RL	-1.15 dB	-0.36 dB	-0.13 dB
BW	258 MHz	278 MHz	187 MHz

5. Conclusions

In the present work, the performance of the 3rd order, parallel-coupled micro-strip band pass filter was improved by modifying the resonators length and using DGS in the ground. The filter was designed using ROTMM10 substrate of thickness 1.6mm and dielectric constant of 0.0022.The insertion loss (-0.13 dB) and return loss(-35.38 dB) obtained with this filter at 3.2GHzshows vast improvement as compared to the insertion loss(-2dB) and return loss(-15dB) reported in [6].

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