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Coupled Line Band Pass Filter with Defected Ground Structure for Wide Band Application

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Abstract
In this paper a novel wideband microstrip band pass filter is proposed. The band pass filter is designed with coupling between two L-shaped microstriplines and is terminated with a high impedance line. The three circle shapes are etched out at the ground plane and is called defected ground structure (DGS), which provides better return loss as well as it reduces harmonics. Simulated and measured results both are in true agreement with each other. Results show that the defected microstrip filter has a good performance, including a wide pass band of 3.0 GHz to 5.6 GHz at 3dB cut off frequencies with bandwidth of 2.6 GHz, and a small insertion loss. The return loss is found to be higher than 15 dB.
Index Terms: Bandpass filter, DGS Filter, Wide Band filter.

I. Introduction

In wireless communications, band pass filters are the most widely used. For the design of microstrip band pass filters, several techniques exist and most of them propose novel filters with advanced characteristics which are based on several structures.

Due to the development of wireless communications and the appearance of new systems there is high demand of small size, low cost filters with high performance. Therefore, miniaturization of band pass filters with improvement of their characteristics is a big challenge in modern filter design.

In modern wireless communication systems, compact size and high performance filters are commonly required to reduce the cost and enhance system performances. Recently, the defected ground structure (DGS) for microstrip lines [1, 3] has become one of the most interesting areas of research owing to their extensive applicability in microwave circuits. Defected ground structure (DGS) is etching geometry which has been proposed to improve rejection in the stopband of a low-pass filter (LPF). However, the DGS has not been used to improve the stopband characteristics of the filter. A particular shape of the slot in a ground plane could also be more appropriate to design a complete circuit on the same substrate. The shape, size, and orientation of a slot can have an influence on performance of the filter and other neighboring circuits. A DGS is an intentionally designed defect on a ground plane that creates additional effective inductance and capacitance. This technique can be used to design microstrip lines with desired characteristics, such as higher impedance, band rejection and slow-wave characteristics. Bandpass filters for ultra-wideband (UWB) radio systems have employed several approaches, such as composite lowpass–highpass construction [4], [5], nonperiodical shunt-stub loading [6], and broadside microstrip- to-coplanar-waveguide (CPW) transition based on surface-to-surface coupling [7]–[10].

Recently, the photonic band gap (PBG) periodic structures and the defected ground plane structures (DGS) have been proposed for suppression of spurious response in the microstrip lowpass filters (LPF) and also in the coupled microstrip line bandpass filters (BPF). However, these techniques are not used to suppress undesired response in the stopband of open-ended stub line based microstrip BPF. The existing DGS configurations provide only the band-reject characteristic, which is not sufficient to adopt the DGS or PBG configuration to a stub type microstrip BPF. In this communication, we report a new DGS based band- accept configuration in a microstrip line. We also report its circuit model. We have combined the band- reject and band-accept DGS configurations with open-ended microstrip stubs to develop a compact 3-pole bandpass microstrip filter [11].

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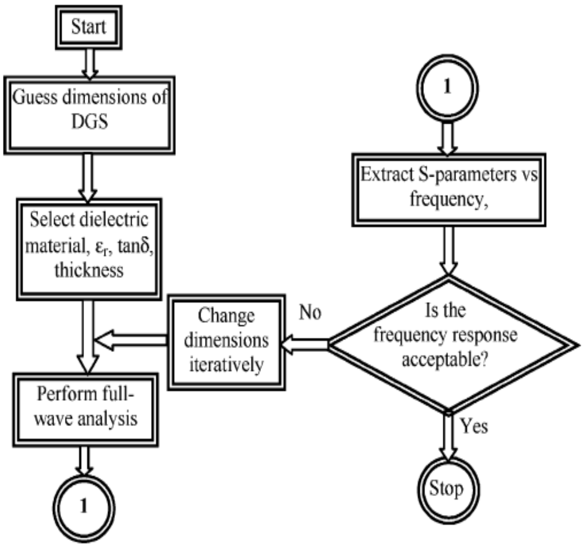

Figure.1 Conventional design and analysis method of DGS [12]

In this paper a novel wideband microstrip filter is proposed. The band pass filter is designed for coupled line with defect at the ground plane. The Defected Ground Structure provides better return loss. It is expected that the broadened width of microstrip line would provide an improved high power-handling capability. A detailed flow chart is given in figure 1. Initially an arbitrary value is chosen for defect and after tuning and optimization; a fixed value of circular DGS is etched at ground plane

II. Design & Simulation

In this paper, a microstripline is used which has two L-shaped ports that are coupled back to back and a high impedance line is placed between them to maximize the coupling effect. Microstripline used in this paper is having FR4 epoxy substrate having permittivity of 4.4, thickness of the microstripline is 1.6 mm and metal thickness t=0.035mm. The width of the port is 2.41 mm and gap width of 0.5mm, while width of low impedance line connected with this port is 0.2mm. This design is simulated on High frequency 3-D simulator. Total length of filter is 45mm and width of filter is 20mm. The two ports of this filter are coupled with high impedance line followed by cylinder of radius 1.3mm and width of 0.65mm and length of terminated line is 20mm. The port is connected with L- shaped line of length 14mm and width is 0.2mm as shown in figure 2 and three circular defects are etched out at ground plane as shown in figure 3.

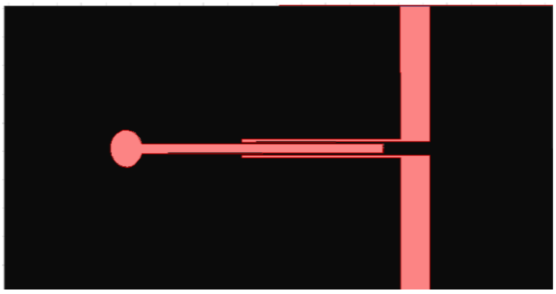

Figure 2. Top view of the proposed filter (HFSS Model)

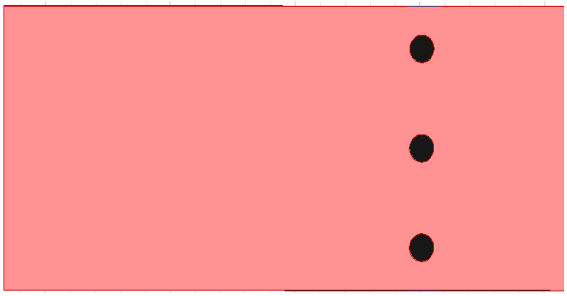

Figure 3. Bottom view of filter with DGS (HFSS Model)

The figure 4 shows the simulated result of S11 and S21. The lower cut-off frequency is 3 GHz and upper cut-off frequency is 5.6 GHz with 2.6 GHz bandwidth. Figure 5 and Figure 6 shows the VSWR and group delay, VSWR (1) and VSWR (2) is exactly identical to each other. Figure 7 and Figure 8 shows the E-field and H-field variation in which field intensity variation is clearly shown.

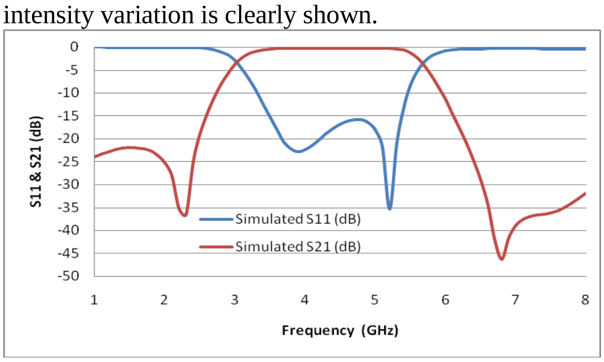

Figure 4. Frequency response of simulated result

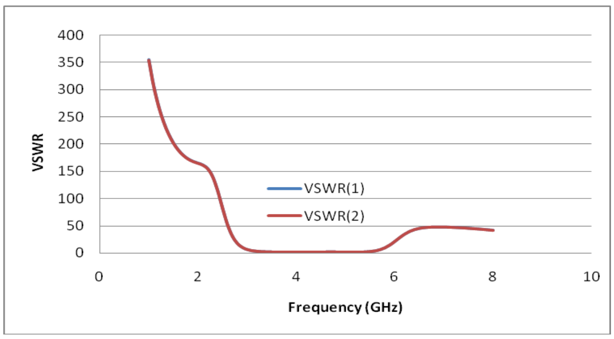

Figure 5. VSWR response

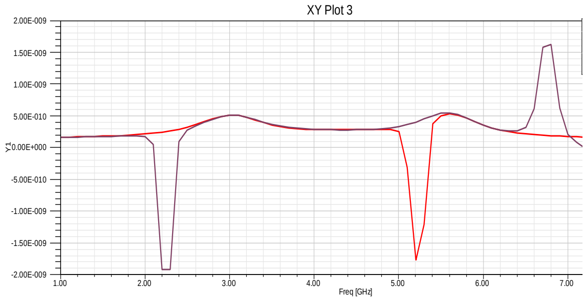

Figure 6. Group delay of S11 and S21

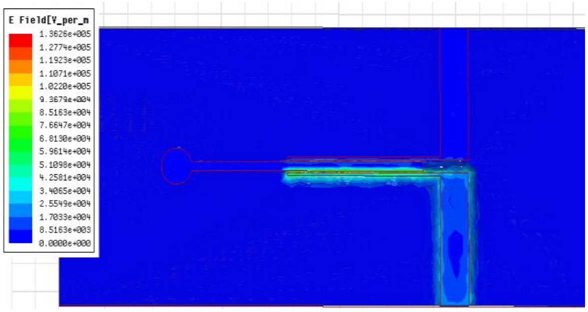

Figure 7. E-Field variation

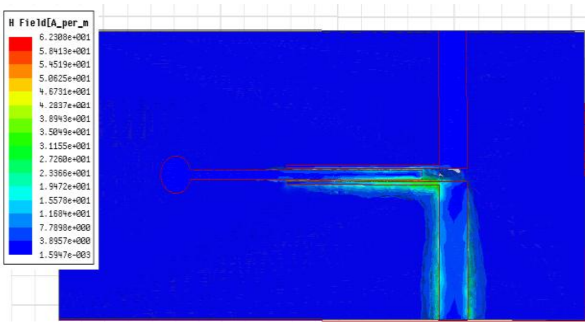

Figure 8. H-Field variation

III. RESULT & OBSERVATION

Sharp cut off transition is observed in Fig [4]. When we vary the dimension of various parameters of defected ground structure for optimization, we realize that the resonance frequency f_0 of DGS cell depends on the physical dimensions of the cell. For example, f_0 can be reduced by using smaller gap between strip, larger area of cell or larger distance between the two cells. Since gap between strips is generally limited by PCB fabrication techniques, increasing the size of the cell is the practical approach of reducing the resonance frequency. If there are floating patches inside the cell, it will exhibit a shift towards lower values. To measure the compactness of the structures, we simulated the transmission coefficient of microstrip lines on top of these structures. The simulations are performed using a full-wave EM simulator. The substrate used in the simulation has the same parameters as the FR4 with a board thickness of 1.6 mm, a dielectric constant of ε_r =4.4, and a loss tangent of 0.02. In the simulations, the width of the center metal traces in all the structures is kept at a fixed value and is the same as the width of the microstrip line.

The compactness of the proposed resonant cell can be understood based on the parameters extracted from the equivalent- circuit model proposed by Woo *et al.* It is observed that the capacitance of the proposed cell is greater than that of the conventional low pass filter, while there is little difference in the inductances. Thus, we can conclude that the extended gap length results in increased capacitance, and the increased capacitance leads to f_o reduction i.e. resonant frequency reduction and size reduction.

DGS have been gaining interest for their planar form and ease of fabrication. They are very useful in the design of LPF, BSF and BPF, since a few DGS can provide a cut-off frequencies and an attenuation pole without a need of periodic array. One advantage of employing DGS is that the fabrication cost can be reduced with a simultaneous improvement of the filter performance. Another advantage is that they can be easily modeled using simple RLC circuits, especially for microstrip line structures. Because of the excellent stop-band and slow-wave characteristics, the DGS have been applied widely to microstrip circuits such as filters, amplifiers and antennas. DGSs are realized by etching defects in the backside metallic ground plane under a microstrip line. A basic and widely used DGS cell is composed of two wide defected areas and a narrow connecting slot. A DGS-slot combination has a simple structure and can be modeled as a parallel LC resonator. Such a structure blocks the signal around its resonant frequency and may be used to introduce a wide stop band for low-pass, band-pass and band stop filters. Such filters have sharp transitions between the pass band and the stop band, low insertion loss in the pass band, wide stop band and high attenuation in the stop band.

The simulation results show that the designed filter has a good sharpness factor, shows multi resonance, has symmetrical response and smaller losses in the passband as shown in Fig. 4. The filter has been simulated using FR4 epoxy as the dielectric, which has a permittivity of 4.4. The transmission and reflection loss characteristics are shown in the Figure 4. The VSWR plot is shown in Figure 5.

The fabricated model is shown in Figure 9 and Figure 10. Figure 11 shows the measured value of S11 and S21, which is almost same as simulated value.

Figure 9. Top view of fabricated model of filter

Figure 10. bottom view of fabricated model of filter

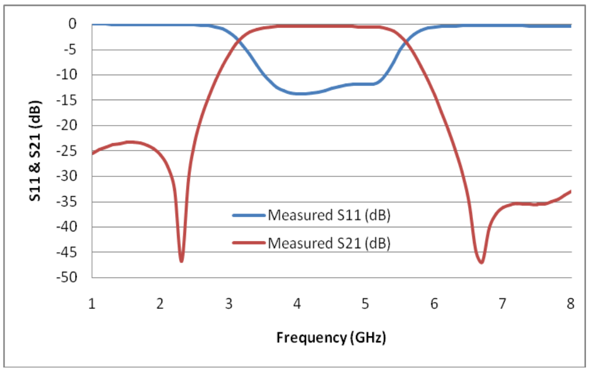

Figure 11. Frequency response of measured result

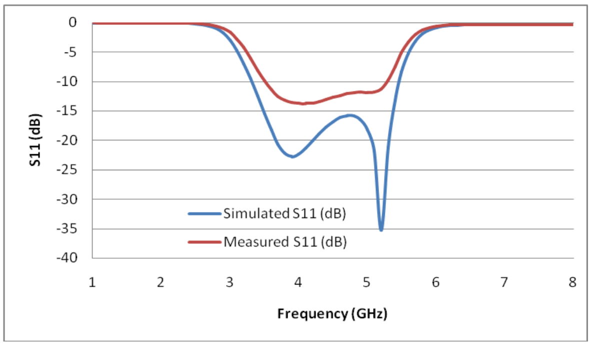

Figure 12. Comparison of simulated and measured result of S11

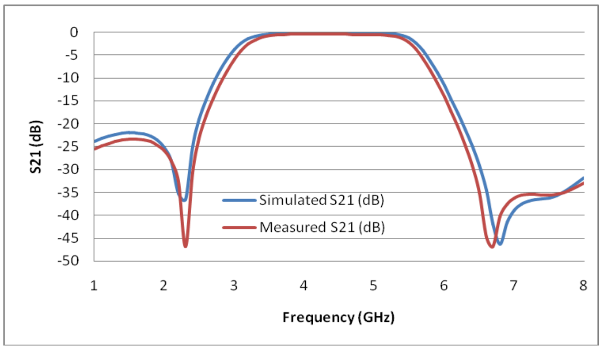

Figure 13. Comparison of simulated and measured result of S21

In figure 12 and figure 13, it is clear that there is very little difference between measured and simulated result. Table 1 clearly shows the various parameters of simulated and measured result.

Table-1

Parameters	Simulated	Measured
S11 at -3dB	3.0529 GHz	3.1 GHz
S21 at -3dB	f_{c1} = 3 GHz f_{c2} = 5.6 GHz	f_{c1} =3.15 GHz f_{c2}=5.55 GHz
Resonant Frequency	4.3 GHz	4.35 GHz
Bandwidth	2.6 GHz	2.4 GHz
Fractional Bandwidth	60 %	55 %

IV. Conclusion

Here we have successfully designed a very compact size of Band Pass filter with a pass band from 3 to 5.6 GHz. There is a very good agreement between simulated results and measured results. There is a small insertion loss, and the return loss is found to be higher than 10 dB. The resonant frequency of simulated result is 4.3 GHz while measured resonant frequency is 4.35GHz. Here we have achieved a very high fractional bandwidth which is almost 60% in simulated results while 55% in measured results.

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