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Design and Simulation of a Band Pass Filter using Defected Ground Structure for Wi-Fi and WLAN Applications

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Abstract: **This paper presents the design and simulationof a metal strip loaded defected ground structure (DGS) based band pass filter (BPF) for Wi-Fi and WLAN applications. A series connected parallel resonant circuit will behave as a BPF. So, for the realization of an inductor of a resonant circuit dumbbell shaped DGS structures is used while to realize a capacitorof aresonant circuit a gap discontinuity is created in transmission line. This filter center frequency is 5.1 GHz and 3-dB impedance bandwidth is 1.1 GHz (4.5-5.6 GHz). It's insertion loss is < 0.2 dB at the center frequency. Simulation is carried out by using a 3D EM Simulator Ansys HFSS.**

Keywords **— BPF, DGS, Wi-Fi, WLAN**

I. INTRODUCTION

Unwanted signals can disturb the performance of microwave systems. So, Microwave systems often requires a device for suppressing unwanted signals from the band of operation i.e.transmission at frequencies which lies in the passband of the filter and attenuate the frequencies which lies in stopband of the filter. This function can be performed by electric filters. These filters are usually categories by their frequency characteristics, namely low-pass, high-pass, bandpass, and band stop. For Wi-Fi and WLAN applications it is required to use BPF. The microwave high-performance Band-Pass Filter (BPF), requires small insertion loss in the pass band and large insertion loss in stop band [1]. Apart from this it also requires a high pass band to stop band transition and vice versa i.e. high selectivity, and small group delay variation in the pass band.

Conventionally microwave filter designing is done with classy computer-aided design (CAD) packages, which are based on the insertion loss method. After decades long researches filters are still a fascinating research area due to continuous technology development. DGS structures also developed in thin film substrates [2].

Defected Ground is a very popular technology for the realization of miniaturized passive microwave components [2-10]. The DGS is realized by creating a defect i.e. etching of any pattern in the ground plane of a planar transmission line. This pattern will disturb the path of the current flowing in the ground plane. It will change the performance of microstrip line [7]. Several DGS geometries performance has been investigated for different shapes. Some simple shapes are square, C-shape [8], circle, triangle [1], etc while some complex-shaped DGS, such as inverse S, U-shape[9] etc. have been recommended to develop more compact LPF and BPF with a sharper transition region. Simple form of DGS slots can be easily modelled as a series connected parallel resonant circuit.

The DGS has two main characteristics: one is slow-wave effect and another one is band stop characteristics. The slow wave effect is useful to achieve the miniaturization of the component while band stop characteristics are useful to achieve the filtering. These characteristics can be altered by varying the dimensions and shapes of DGS. In this project, a band pass filter is developed by using a metal loaded square patch head DGS. The structure is simulated by using 3D EM simulator Ansys HFSS. In section -II, the filter configuration and design is presented. In section – III, detailed description of DGS modeling is covered. Section-IV covers the result analysis and in the last section we have concluded the paper.

II. FILTER CONFIGURATION AND DESIGN

The filter is designed on Neltec substrate with height (h) = 1.524 mm, dielectric constant (εr) = 3. The dimension of substrate is Ls × Ws. The thickness of conductor is 0.07 mm. Initial Dimensions of various layers have been taken by considering the computational formulas. Optimized dimensions obtained by using 3-D Electromagnetic Simulator with parametric variations. All the dimensions of filter are given in Table-1..

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TABLE: 1

Parameter	Value (mm)
Ls	20
Ws	19.5
L1	6.65
L2	5.9
L3	1.9
W1	3.4
W2	2.0
W3	1.7
G	0.13
g1	0.4
A	3.5
B	3.5
g3	1.5
g4	0.3
L slot	6
L strip	11

The top view and back view of the filter is shown in Figure 1. In this configuration two U-slots are introduced in a 50 Ω transmission line to realize a series capacitor. This capacitor is very much required for the realization of BPF.

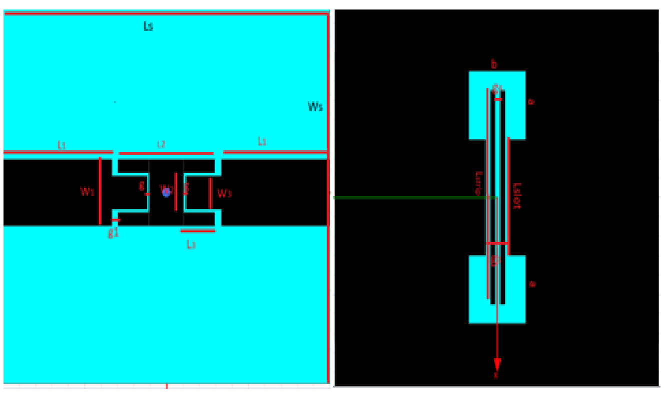

Figure 1(a): Top View of proposed BPF, Figure 1(b): Back View of proposed BPF

III. MODELING OF DGS

In this design a metal strip loaded dumbbell shaped(DB)-DGS is used for realizing a band pass filter[2]. Equivalent circuit of DB-DGS is shown in figure 2 –

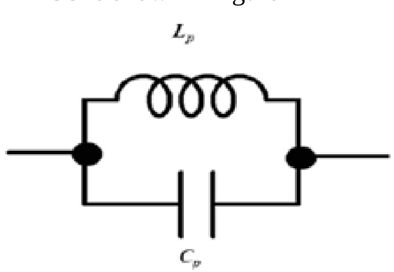

Figure 2 :Equivalent circuit of DB-DGS

Equivalent capacitor and inductor value can be calculated by equation (i) and (ii) respectively [4] –

$$C_p = \frac{5 f_c}{\pi[f_0^2 - f_c^2]} \text{pF} \quad \text{(i)}$$

$$L_p = \frac{250}{C_p(\pi f_0^2)} \text{ nH} \quad \text{(ii)}$$

Here f_0 is the resonance frequency and f_c is the cut-off frequency.

After loading a metal strip in the joining slot of square DB-DGS a better effective parallel capacitance is realized. In proposed structure two U -slots are used to realize a series capacitance. The modeling of this structure can be done by-

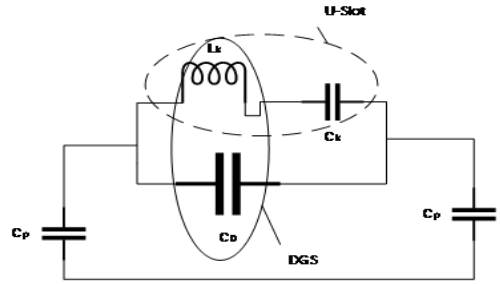

Figure 3: Equivalent circuit of proposed Filter

The proposed circuit has both type of resonances i.e. series resonance and parallel resonance. The series connected series resonance will provide the pass band and series connected parallel resonance circuit will provide the stop band response. For the sharp rejection the stop band center frequency should be near to the pass band. Equivalent capacitor and inductor values for the modified circuit can be calculated by equation (iii), (iv) and (v) respectively [4] -

For series resonant circuit –

$$C_k = C_0\left[\frac{f_h^2}{f_0^2} - 1\right] \quad \text{(iii)}$$

$$L_k = \frac{1}{4\pi^2 f_0^2 C_K} \quad \text{(iv)}$$

$$f_0 = \frac{1}{2\pi\sqrt{L_k C_k}} \text{(v)}$$

For parallel resonant circuit –

$$C_k = C_0\left[\frac{f_0^2}{f_l^2} - 1\right] \text{(vi)}$$

$$L_k = \frac{1}{4\pi^2 f_l^2 C_K} \text{(vii)}$$

$$f_l = \frac{1}{2\pi\sqrt{L_k C_k}} \text{(ix)}$$

Here $f_0, f_h, and\ f_l$ are resonant frequencies.

For reducing the resonance frequency of BPF, the value of series capacitance can be increased. Higher value of series capacitance can be achieved by using more number of slots beneath the conducting strip. The increased capacitance value will also provide it will provide narrow response.

IV. RESULTS ANALYSIS

For the characterization of the filter impedance matching in pass band, insertion loss in pass band as well as in stop band both the characteristics are important and are shown in Figure. 4 and 5 respectively. The band pass filter is designed for f_0 = 5.1 GHz. Reflection coefficient is < -22 dB and insertion loss of the filter is < 0.2 dB at f_0. The 3 dB

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bandwidth is 1.1 GHz. The lower and upper cut-off frequency of the filter is 4.5 GHz and 5.6 GHz respectively. The attenuation of the filter is increased in a very sharp way after 7 GHz. This sharpness is due to existence of transmission zero. By controlling the position of transmission zero it is possible to provide sharp pass band to stop band transition. Figure.6 shows the phase response of S_{21}. As per the phase response the series resonance of the filter is occurs at 5.1 GHz, so it is providing the pass band near the resonance frequency. At 7.4 GHz it is providing the parallel resonance. So, after this point sharp transition can observe. After this parallel resonance immediate series resonance is occurring, this is very weak in nature. The S_{12} and $_{S22}$ response of the filter are same as S_{21} and S_{11}.This is due to the structure symmetry.

Group delay of the filter should be Figure 7 shows the group delay response of the filter. In the pass band of operation, the group delay is less than 4 ns and at transmission zero frequency the group delay is very high. The shape of the group delay response is matched with the S_{21} response of the filter. This filter is useful for WLAN (5.1-5.5 GHz in India) and Wi-Fi (5.4 GHz) applications.

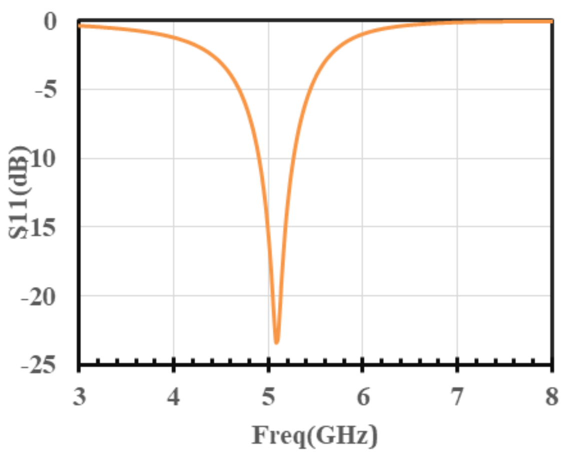

Figure 4: $|S_{11}|$ of proposed Filter

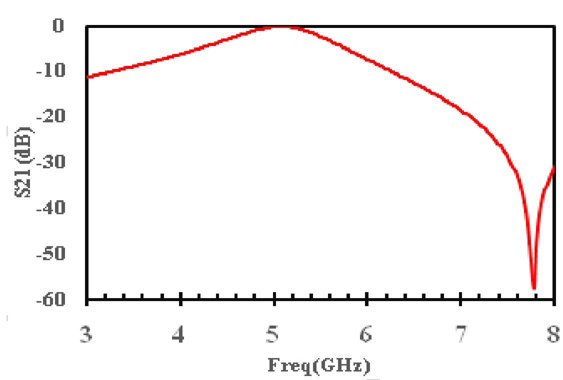

Figure 5: $|S_{21}|$ of proposed filter

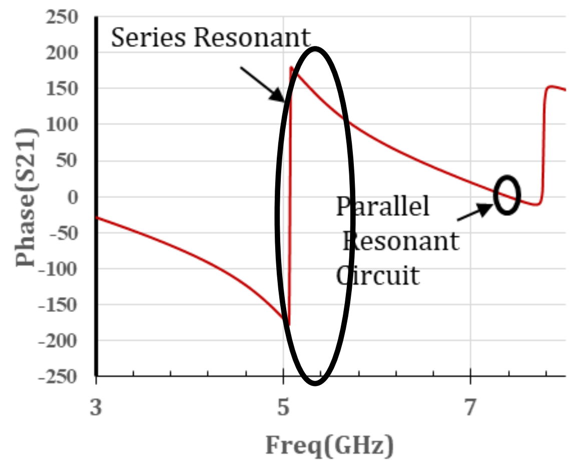

Figure 6: phase(S_{21}) of proposed filter

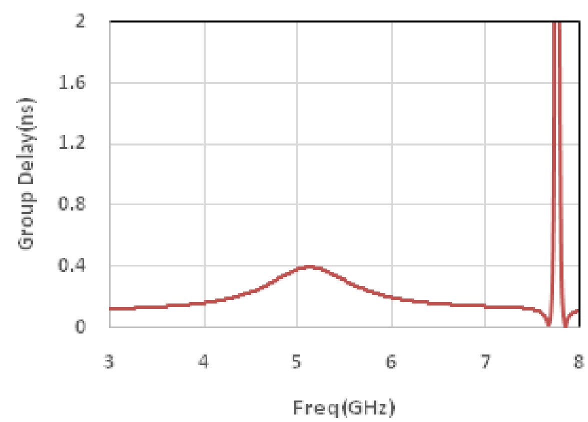

Figure 7: Group delay response of proposed filter

V. CONCLUSION

BPF characteristics are investigated with new metal loaded square head (dumbbell) -DGS. It shows the flat response in the pass band with sharp rejection in the stop band due to creation of transmission zero near the pass band. Three resonance behaviors are observed. One resonance is responsible for pass band and another two are responsible for better stop band. The Pass band Bandwidth (3-dB) of the filter is 1.1 GHz. The insertion loss of the filter is < 0.2 dB at the resonance frequency (5.1 GHz).Group delay of the filter is flat in nature. Flatness of the response lies within ± 2ns. It can be used for Wi-Fi,WLAN and for many other applications.

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