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Design and Analysis of Microstrip Hairpin-Line Band pass Filter

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Abstract : In this paper, two square shape defected ground structure (DGS) are used for designing a novel hairpin-line narrow band microstrip band-pass filter and these structures are linked by a path where etching process is applied in the ground plane. The path length of DGS cell is 10.6 mm and the path width is 0.5 mm where the dimensions of square shape defected ground structure is 2 mm. The mid-band frequency of the designed filter is 2.22 GHz which is applicable for the satellite and radar communication for the purpose of S-Band. The bandwidth of proposed filter is 1.99 GHz to 2.45 GHz which is useful for narrowband communication. The proposed filter has minimum insertion loss of 0.2946 dB and maximum return loss of 46.64 dB at mid-band frequency 2.22 GHz. Output characteristics of microstrip filter is judged by using simulation tool IE3D 14.1 EM which is based on method of moments (MOM). The proposed microstrip band pass filter has a coverage area of (34.8 mm× 18.25 mm) 635.1 mm2 for the top layer and (21.85 mm× 14.5 mm) 316.825 mm2 for the ground layer which is more compact as compared to other existing band pass filter designs.

Index Terms - **Microstrip Band pass Filters,DMS,DGS, MOM, S11 Parameters, Return loss, S21 Parameters, Insertion loss**

I. INTRODUCTION

Research work is continuously going on in the field of Defected ground structure (DGS) for various microwave band applications [1-6]. Various types of microwave devices such as power amplifier, patch antennas, directional couplers, filters and power dividers are fabricated using DGS technique. Minimum insertion loss, sharp cutoff and high return loss are the basic specification of an ideal microstrip band pass filter. Defected ground structure (DGS) are of increasing importance in band pass filter applications. Various designs have been proposed for microwave devices [1-14]. Defected ground geometry etched in the ground plane of microstrip line has been proposed by many researchers and these structures are constructed by making a path in the reverse side of metallic ground plane [7].DGS along with the micro-strip line exhibits a resonant property. The dimensions and structure of the connecting slot depends upon its resonant frequency. Different types of defected structures have been fabricated by using different shapes such as, dumbbell, circular and spiral type structure [3-6]. Two uniform U-shape defected ground structures have also been proposed for microstrip low-pass filter design with wide rejection band [3]. UWB band pass filter can also be designed using Defected microstrip structures [6]. It consists of DMS resonators connected in cascade manner. Micro strip hairpin band pass filter has also designed with open stubs DGS [7].

Microstrip filters could also be designed with etching a simple U-shaped slot in the center of microstrip line by using DMS [8]. The spurious response can be suppressed through etching an open ring in the DGS [9]. DGS and DMS are the most interesting field of scientists and researchers in various wireless applications such as microwave imaging in a variety of microstrip antennas and filters [10-12].

In this paper a DGS band pass filter using hairpin structure is proposed for narrow band applications using square head geometry. Square shape DGS unit offers much improved scattering parameters in the pass band. The simulated results have been exposed with good agreement for microstrip band pass filter fabrication using DGS.

II. SQUARE HEAD DGS DESIGN FOR THE FILTER

Micro strip hairpin filter has more significance now days because of its less size and simple structure. These filters are constructed by U shape structure which is obtained by folding the resonators of parallel-coupled, half-wavelength resonator filter. Figure 1 represents an element of hairpin structure and Figure 2 represents the corresponding RLC resonant structure of hairpin band-pass filter.

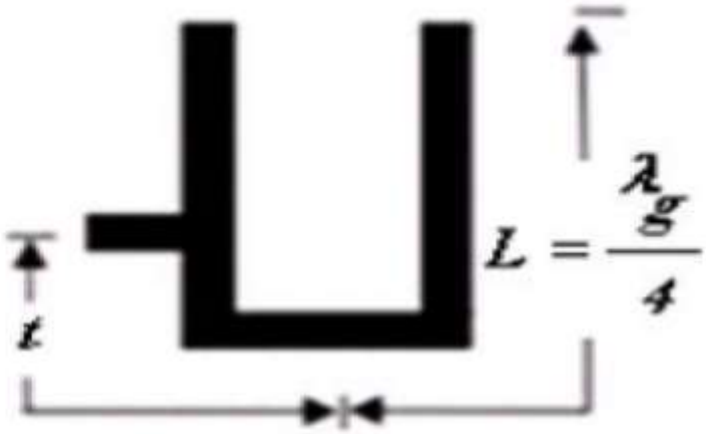

Figure 1. A Constituent of Proposed Band pass Filter

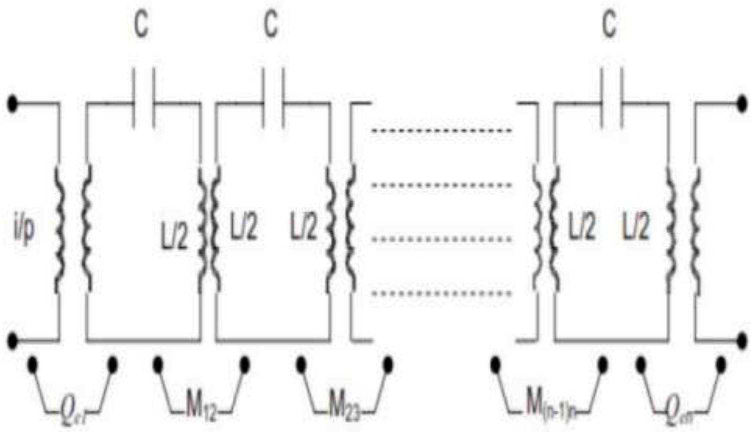

Figure 2. Resonant Circuit of Proposed Band pass Filter

Here combination of inductor and capacitor are used for modeling the resonators. Mi,i+1 represents the mutual coupling coefficient between two resonators. The input and output quality factors are Qe1 and Qen. These parameters are used for determining the size and gap in hair-pin filter which can be derived from the designed equations [1]

$$Q_{e1} = \frac{g_0 g_1}{FBW} \qquad \text{(i)}$$

$$Q_{en} = \frac{g_n g_{n+1}}{FBW} \qquad \text{(ii)}$$

$$M_{i,i+1} = \frac{FBW}{\sqrt{g_i g_{i+1}}} \quad for\ i = 1\ to\ n-1 \qquad \text{(iii)}$$

The normalized low pass parameters of the desired band pass filter approximation are denoted by g0, g1, g2 ………. gn+1 and FBW is the fractional bandwidth. In hairpin filter if self-coupling is neglected then the tapped position is computed as shown in Figure 1 [1]. If Z0 is the terminating line Impedance, Zr is the characteristic impedances and L is the section size of hairpin filter then tapping position (t) is easily computed as given in equation (iv).

$$t = \frac{2L}{\pi} \sin^{-1}\left(\sqrt{\frac{\pi Z_0}{2Q_e Z_r}}\right) \qquad (iv)$$

The section size of hairpin filter is equal to quarter guided wavelength [1]

$$L = \frac{\lambda_g}{4} = 22.25\ mm \qquad (v)$$

Following are the design parameters for third order filters: Centre frequency (f0) = 2.22 GHz, Substrate thickness, h = 1.6

Fractional Band width, FBW = 0.2

Di-electric constant, εr = 4.4 mm, Loss tangent, tanδ = 0.02

Number of poles (n = 3) Passband ripple= 0.1 dB Normalized frequency Ωc = 1, g0 = g4 = 1.0, g1 = g3= 1.0316 g2 = g4 = 1.1474.

Line width of hairpin resonators= 2 mm Characteristic line impedance, Zr = 59 ohm Separation between the two arms= 4 mm M1,2 = M2,3 = 0.18 and

Qe1= 5.16.

The tapping location (t) =7.9 mm

The single defect can produce an attenuation pole and sharp cutoff. A path is formed between both the square shapes defected ground structure in the bottom side of the

Structure through etching process, as shown in Figure 3. DGS unit has slot length (l) 10.6 mm and slot width (s) 0.5 mm. The length and width of the square shape

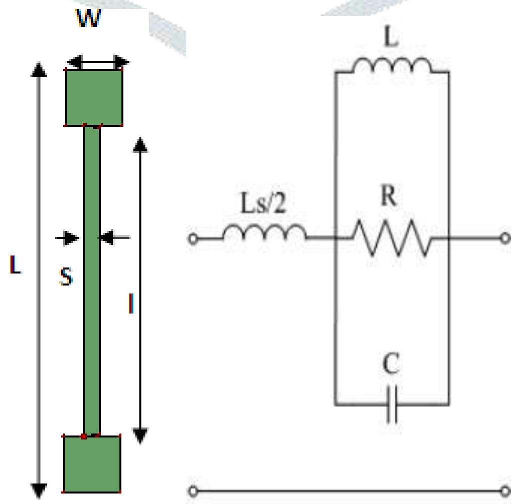

Figure 3. An element of square shape defected ground structure and its equivalent circuit structure is 2 mm. The edge length of the square shape DGS depends upon resonant

characteristics. IE3D Layout of DGS cell and its corresponding resonant circuit are illustrated in Figure 3.

Where Z0 is the characteristic impedance, ωc is the 3-dB cutoff frequency and ω0 is the angular resonance frequency. The square shape DGS are employed in band pass filter design for achieving good performance and more square shape DGS cells can be added for designing the desired microstrip band pass filter characteristics.

II DESIGN LAYOUT AND RESULTS OF SQUARE HEAD DGS FILTER

The upper and below layer of proposed microstrip filter is shown in Figure 4 and 5. Figure 6 shows the entire structure of microstrip hairpin-line filter using DGS. Figure 7 represents the identical resonant circuit of the DGS filter through upgraded measurements in view of the investigation of unit cell. The IE3D simulated response of basic microstrip band pass filter is given in figure 8. Figure 9 shows the enhanced performance of microstrip band pass filter with two square shape DGS cell. Glass Epoxy FR4 dielectric substrate is used for the fabrication of microstrip filter which has following properties.

Thickness of the Substrate =1.6 mm.

Permittivity=4.4

Cut-off frequency=2.22 GHz

FILTER DIMENSIONS FOR THE UPPER LAYER

Total width of Filter = 18.25 mm Whole length of Filter = 34.8 mm

Spacing between two U shaped resonators = 0.4 mm. The length of first U shaped resonator =17.25 mm.

The length of second U shaped resonator =18.25 mm. Width of U shaped resonators= 2 mm.

Width of 50Ω microstrip line =3 mm.

Length of 50Ω impedance Characteristic line =5 mm.

FILTER DIMENSIONS FOR THE BOTTOM LAYER DEFECTED GROUND STRUCTURE

Total length of DGS structure = 18.6 mm. Total width of DGS structure = 14.6 mm. Spacing between two DGS units = 14.6 mm.

Edge length of the square shape DGS (W) = 2 mm, Slot length (l) of all two DGS=10.6 mm,

Slot width (s) of all two DGS=0.5 mm

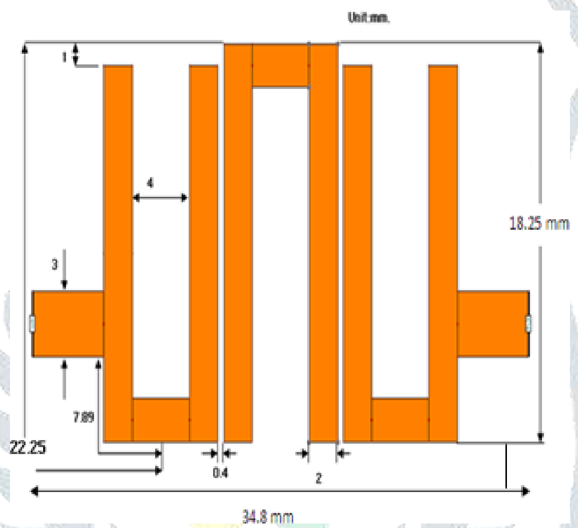

Figure 4. Top layer structure of DGS microstrip filter

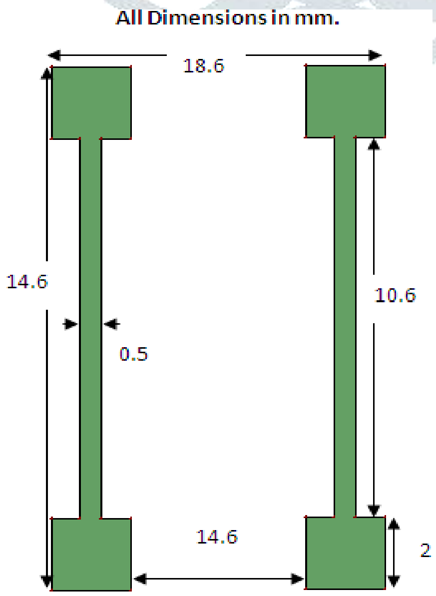

Figure 5. Below layer structure of DGS microstrip filter

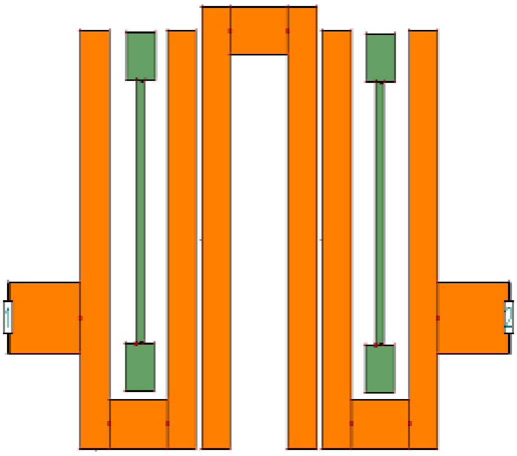

Figure 6. Complete Design of the DGS band pass filter

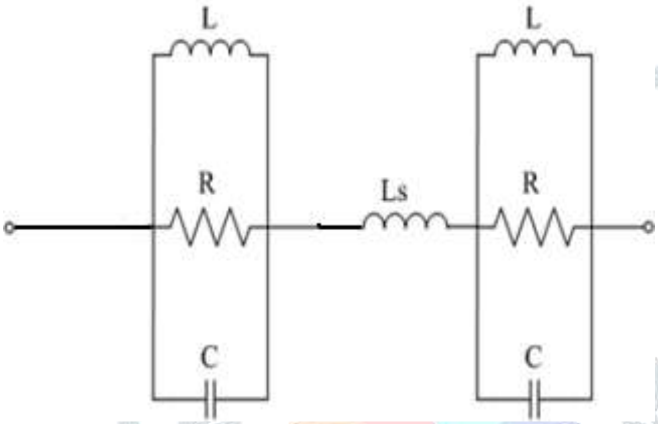

Figure 7. Equivalent RLC Circuit of the proposed band pass filter

The performance correlation of normal and Defected Ground structure (DGS) design of DGS microstrip filter is given in Figure 8 and Figure 9. It is obvious from the outcomes acquired from both the design characteristics that DGS structure exhibits more sharp and exact response when contrasted with basic design of filter. The insertion loss of basic design is 0.2954 dB and return loss is 27.4 dB at mid-band frequency 2.22 GHz as shown in Figure 8 whereas the proposed microstrip filter using DGS structure is shown in Figure 9 which exhibits the 0.2946 dB insertion loss and 46.64 dB return loss. Consequently it is undoubtedly recognized that DGS configuration is greatly improved when contrasted with normal design in terms of simulated performance, insertion loss and return loss. Phase delay characteristics of the DGS structure are shown in Figure 10. Current distribution and three dimensional view of the proposed microstrip structure are shown in Figure 11 and 12 respectively. Impedance matching characteristics of the microstrip filter is represented with the help Smith as shown in Figure 13.

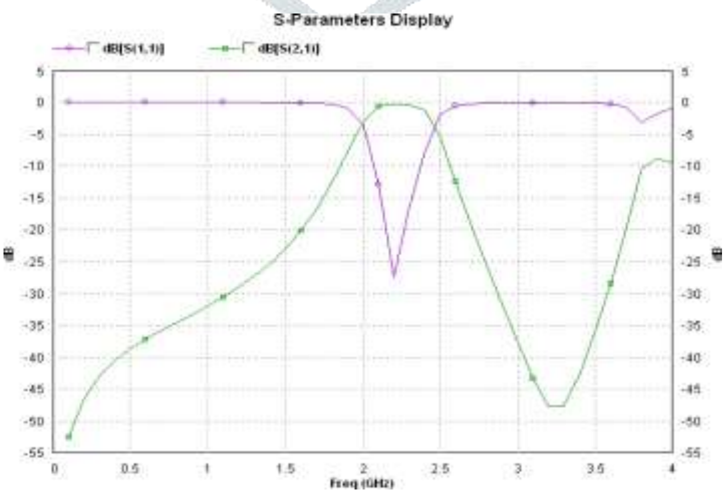

Figure 8. Simulated result of simple microstrip band-pass filter without DGS

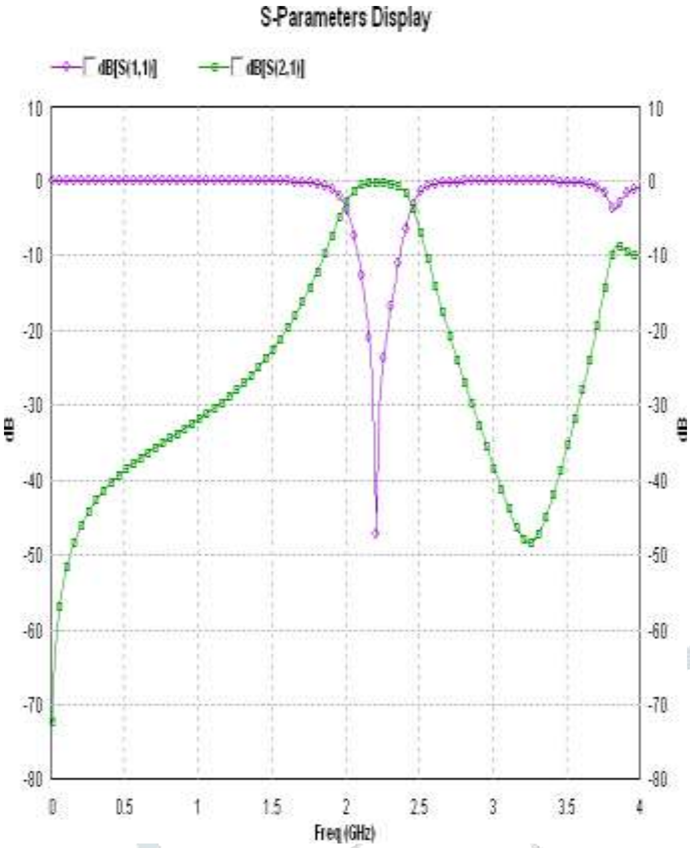

Figure 9. Simulated result of DGS microstrip band- pass filter

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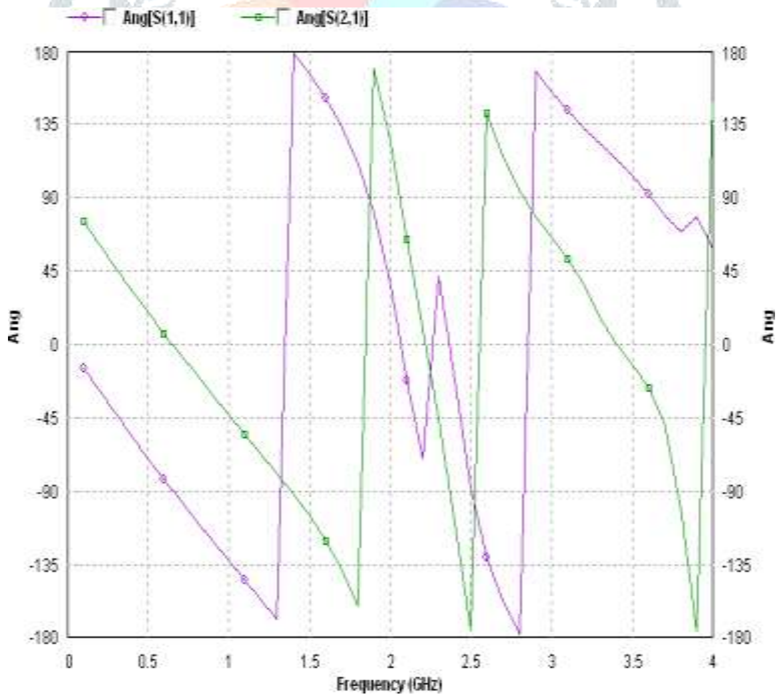

Figure 10. Phase characteristics of the DGS filter

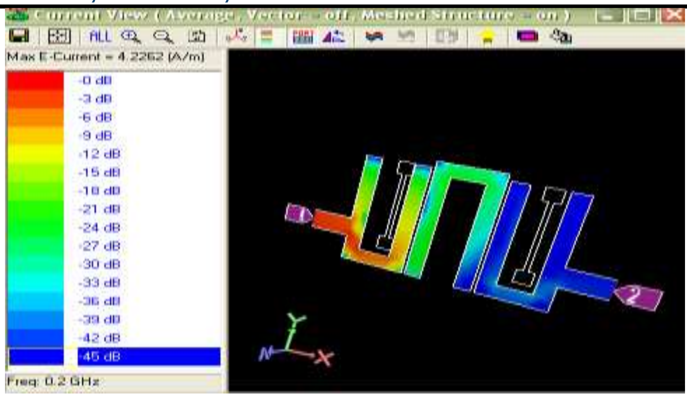

Figure 11. Current distribution in the proposed microstrip band pass filter

Figure 12. 3-D View of the proposed filter structure

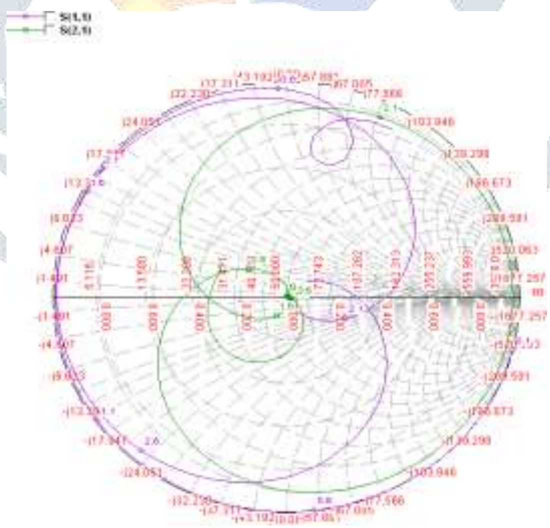

Figure 13. Smith Chart of the proposed design

CONCLUSION

It is evident from the filter characteristics as shown in Figure 9, 2.22 GHz is the mid-band frequency for the proposed microstrip filter design which is relevant for S-band applications, for example, Radar and satellite communication. The performance of band pass filter can be improved by using DGS structure and a sharp cut-off frequency response is obtained with improved return loss and insertion-loss and compact structure.

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