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CIRCULAR DEFECTED GROUND MICROSTRIP BAND-REJECT FILTER DESIGN FOR RADAR COMMUNICATION

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Abstract:
In this paper, a novel narrow band microstrip band-reject filter is designed using three circular shape defected ground structure (DGS). Three circular shape defected ground structure are linked by a path in the ground plane where etching process is applied. The path length of middle DGS cell is 8 mm and the path length of corner DGS cell is 11 mm whereas the path width of all three DGS cell is 0.6 mm and the radius of circular shape defected ground structure is 2.1 mm. The mid-stop band frequency of the designed filter is 1.61 GHz which is applicable for the satellite and radar communication for the purpose of S-Band. The stop bandwidth of proposed filter is 1 GHz to 2.2 GHz which is useful for narrowband communication. The proposed filter has minimum return loss of 0.11 dB and maximum insertion loss of 60 dB at mid stop-band frequency 1.61 GHz. IE3D 14.1 EM simulation tool is applied for finding out the desired outcome. The proposed microstrip band stop filter has a coverage area of (35.1 mm× 14.4 mm) 505.44 mm^2 for the top layer and (16.6 mm× 19 mm) 315.4 mm^2 for the ground layer which is more compact as compared to other existing band stop filter designs.

Keywords: *Microstrip Band Stop Filters; DGS; S-Band; S-Parameters.*

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1. Introduction

Defected ground structure (DGS) are of increasing importance in band stop filter applications and have been proposed and designed for obtaining the desired parameters. They can be used to design compact filters keeping the performances better than conventional filters [1]. A large number of 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 [2]. Rahman et.al suggested that arrowhead slots give rise to sharper cutoff at the cost of decreased stop-bandwidth [3]. Defected microstrip structures can also be realized with the help of slow wave effect technique and electromagnetic coupling which provides low insertion loss and broad pass-band in the stop-band [4]. The advantage of such types of structure is lower radiation losses, good resonance and smaller size due to slow wave effect as compared to other DGS. The performance of band-stop filters can be enhanced by joining the effect of Defected Microstrip Structures and Defected Ground structures [5]. A new spiral type Defected Microstrip Structures is used to provide resonance nature in the frequency response and high slow wave factor is provided by the defected Ground structure. Defected ground structures (DGS) with spurline filter is used for providing good stop band characteristics in band-stop filter [6]. Adaptive neuro-fuzzy inference system can also be applied for designing of dual band bandstop microstrip defected ground structure filters so that the physical dimensions of filters is obtained with high accuracy in less time[11]. Latest research work is highly focused on designing of different microstrip antennas and filters using DGS and DRA [7-13].

In this paper a DGS band stop filter using circular shape defected ground structure is proposed for narrow band applications. Here we use the circular head geometry with some parametric variation for still better characteristics. The application of circular shape DGS unit is to provide improved insertion loss and return loss as well as a good performance in the stop band. The simulated results have been exposed with good agreement for microstrip band stop filter fabrication using DGS.

2. Design of Proposed Microstrip Band Reject Filter Using Circular Head Dgs

Microstrip band-stop filter has more significance now days because of its less size and simple structure. These filters are constructed by adding two F-shape structures as shown in figure 3. Figure 1 represents the corresponding RLC equivalent resonant structure of band-stop filter.

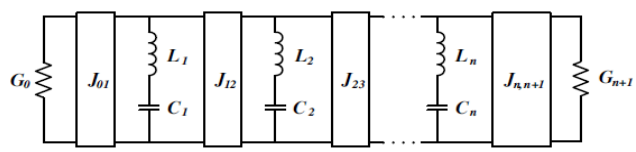

Figure 1: Resonant circuit of proposed band-stop filter

Here combination of inductors, capacitors and admittance inverters are used for modeling the resonators. These parameters are used for determining the size and gap in proposed filter which can be derived from the designed equations [1]

$$L_i = \frac{1}{\omega_c^2 C_i} = \frac{\triangle g_i}{\omega_c Z_0} \quad (i = 1 \; to \; n) \qquad (i)$$

$$J_{0,1} = \sqrt{\frac{\omega_c G_0 C_1}{\triangle g_0 g_1}} \qquad (ii)$$

$$J_{i,i+1} = \frac{\omega_c}{\triangle} \sqrt{\frac{C_i C_{i+1}}{g_i g_{i+1}}} \quad for \; i = 1 \; to \; n-1 \qquad (iii)$$

$$J_{n,n+1} = \sqrt{\frac{\omega_c C_n C_{n+1}}{\triangle g_n g_{n+1}}} \quad for \; i = 1 \; to \; n-1 \qquad (iv)$$

Fractional bandwidth (FBW) = $\frac{f_2 - f_1}{f_0}$ (v)

Where f_1 *and* f_2 are the lower and upper band-edge frequencies and f_0 is the mid-stop band frequency. The normalized low pass parameters of the desired band reject filter approximation are denoted by g_0, g_1, g_2 ……… g_{n+1}. Z_0 and G_0 is the terminating line Impedance and conductance respectively where G_0=1/ Z_0. L_i and C_i are the inductive and capacitive elements of microstrip filter respectively. ω_c is the angular mid stop-band frequency. $\omega_c = 2\pi f_c$ where f_c is the mid-stop band frequency of the filter. $J_{i,i+1}$ is the Characteristics admittance (Y) of J-inverters. An ideal J- inverter may be defined as a two-port network that shows distinctive nature at each frequency. It means if an admittance Y_2 is linked at one port then the admittance Y_1 of the another port is derived as

$$Y_1 = \frac{J^2}{Y_2} \qquad (vi)$$

Where J is real quantity and known as the characteristic admittance of the inverter. A phase shift of ±90 degrees or an odd multiple of it is provided by the inverter because if admittance Y_2 of the one port is inductive or conductive then the admittance Y_1 of another port may be conductive or inductive. A capacitance parallel with a J- inverter on both sides is equivalent to a series inductance from its peripheral. The J- Inverters can change the admittance levels according to J parameters. These qualities of J-inverters are applied for altering a filter circuit to its equivalent form for realization of microstrip structures.

Following are the design parameters for the proposed filter: Mid stop-band frequency (f_c) = 1.6 GHz,
Substrate thickness, h = 1.6
Fractional Band width, *FBW* = 0.75
Di-electric constant, ε_r = 4.4,
Loss tangent, tanδ = 0.023
Passband ripple= 0.1 dB
Normalized frequency Ωc = 1,
Number of open stub resonators (n) = 4
For n=4 and fractional bandwidth (FBW) = 0.7, the values of all the parameters are obtained by using designed equations [1].
$g_1 = g_4$ = 0.60366, $g_2 = g_3$= 1.09802,
$J_{12} = J_{34}$ = 0.71101, J_{23}= 0.67313
Line width of all resonators= 1 mm
Characteristic line impedance, Z_0 = 50 ohm

The single defect can produce an attenuation pole and sharp cutoff. The proposed DGS cell is constructed by etching a path between both the circular shapes defected ground structure in the bottom side of the structure, as shown in Figure 2. DGS unit has slot length (l) of 8mm, 10 mm and slot width(s) 1 mm.The radius of the circular shape structure is 2 mm. The resonant characteristics of the circular DGS are mainly affected by its radius. The proposed DGS unit and its equivalent resonant circuit are illustrated in Figure 2.

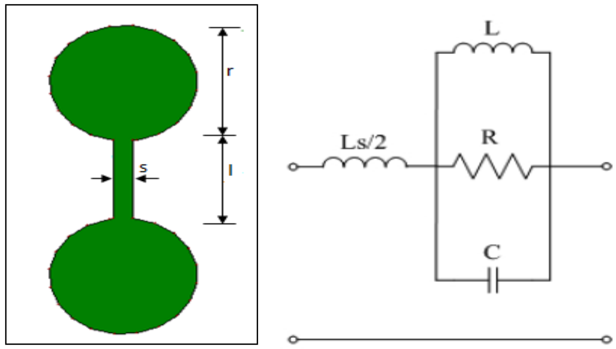

Figure 2: An element of circular shape defected ground structure and its equivalent circuit

If ω_0 is the angular resonance frequency, Z_0 is the characteristic impedance and ω_c is the 3-dB cutoff frequency. Then the corresponding resonant (L-C-R) parameters of the proposed structure are calculated as given below [2].

$$C = \frac{\omega_C}{2Z_0\ (\omega_0^2 - \omega_C^2)} \qquad (vii)$$

$$L = \frac{1}{4(\pi f_0)^2 C} \qquad (viii)$$

$$R = \frac{2Z_0}{\sqrt{\frac{1}{|S_{11}(\omega_0)|^2} - \left(2Z_0\left(\omega_0 C - \frac{1}{\omega_0 L}\right)\right)^2 - 1}} \qquad (ix)$$

The circular shape DGS are employed in band stop filter design for achieving good performance and more circular shape DGS cells can be added for designing the desired microstrip band stop filter characteristics.

3. Design and Results

Figure 3 and 4 represent the top and bottom layer of proposed microstrip band elimination filter and Figure 5 illustrates the complete structure of microstrip band-reject filter using DGS. Figure 6 represents the corresponding resonant structure of the band reject filter. Figure 7 represents the performance of simple microstrip band stop filter without any defected ground structure (DGS) and Figure 8 illustrates the improved characteristics of microstrip band stop filter using circular type DGS. The length of stub is directly proportional to its parallel equivalent capacitance. FR4 dielectric substrate is used for fabrication of filter prototype which has following design parameters.

Relative Permittivity / Dielectric constant (ε_r) =4.4
Substrate height/ thickness (h) =1.6 mm.
Mid stop-band frequency (f_c) =1.6 GHz
Top structure Dimensions of the filter:
Total length of Filter = 35.1 mm

Total width of Filter = 14.4 mm
Maximum Spacing between two F- shaped resonators = 30.1 mm.
Minimum Spacing between two F- shaped resonators = 4 mm.
The length of both F- shaped resonator =13.15 mm.
Width of F- shaped resonators= 1 mm.
Width of 50Ω microstrip line =3 mm.
Characteristic impedance 50Ω line length=2.5 mm.

Defected ground structure Dimensions of the filter

Total length of DGS structure = 16.6 mm.
Total width of DGS structure = 19 mm.
Spacing between two DGS units = 5 mm.
Radius of the circular shape DGS = 2 mm,
Slot length (l_c) of middle DGS=8 mm,
Slot length (l) of corner DGS=11 mm
Slot width (s) of all three DGS=0.6 mm

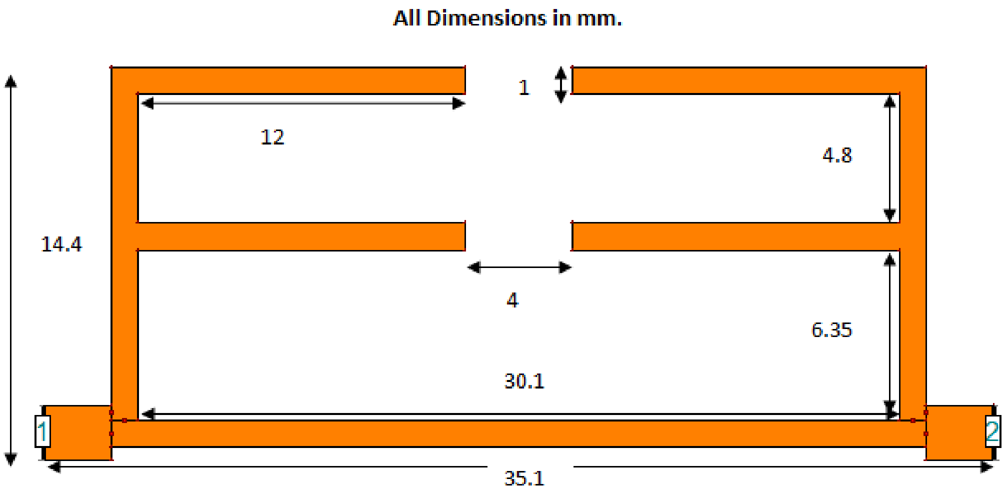

Figure 3: Top layer of the proposed microstrip band-elimination filter

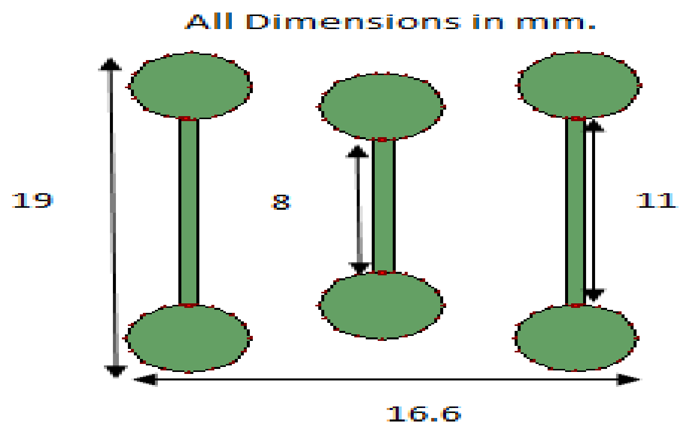

Figure 4: Ground layer of the proposed microstrip filter

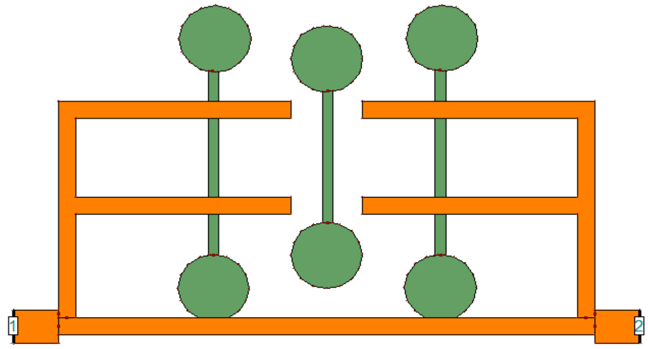

Figure 5: Complete Design of the band stop filter

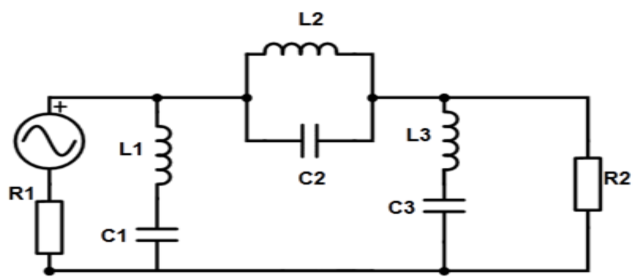

Figure 6: Equivalent RLC Circuit of the proposed band stop filter

Figure 7 and Figure 8 represents the comparison of Simple and Defected Ground (DGS) design performance of proposed microstrip filter. Simulated performance exhibits that DGS structure has more sharp and accurate results as compared to general filter structure. The insertion loss of the simple microstrip filter is only 52 dB and return loss is 0.3 dB at mid-stop band frequency 1.6 GHz as illustrated in Figure 7 whereas the proposed microstrip filter using DGS structure exhibits the 60 dB insertion loss and 0.11 dB return loss as shown in Figure 8. DGS design has more improved response, insertion loss and return loss as compared to simple filter structure. Figure 9 illustrates the phase charateristics of the filter which shows the angle variation properties in DGS. Current distribution and three dimensional view of the proposed microstrip structure are shown in Figure 10 and 11 respectively. Impedance matching characteristics of proposed microstrip filter design is plotted by using Smith Chart as shown in Figure 12.

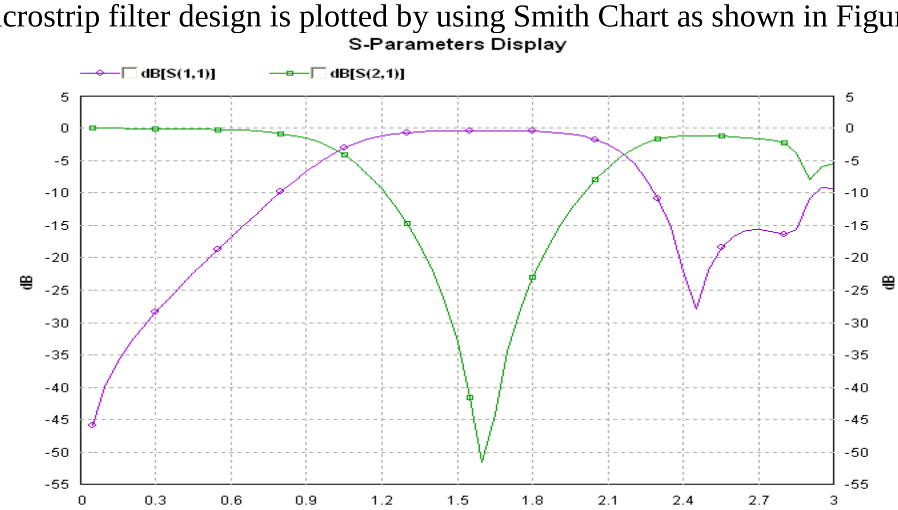

Figure 7: Characteristics of Common microstrip band-reject filter

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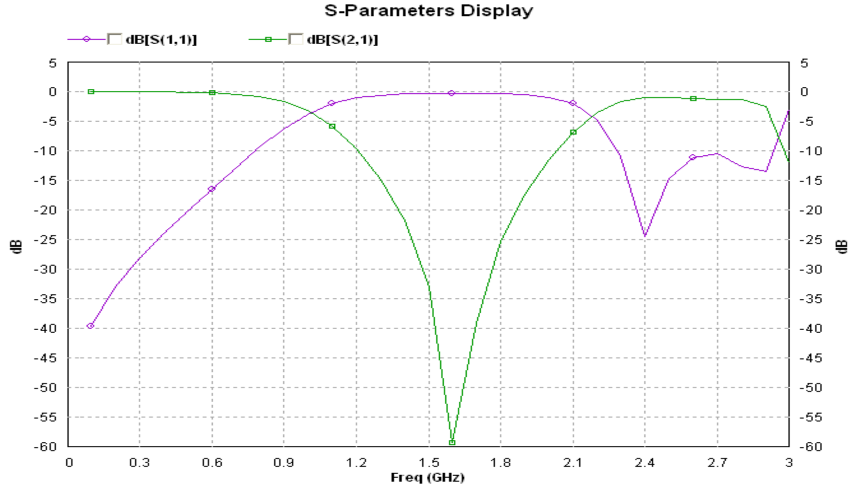

Figure 8: Characteristics of DGS microstrip band- reject filter

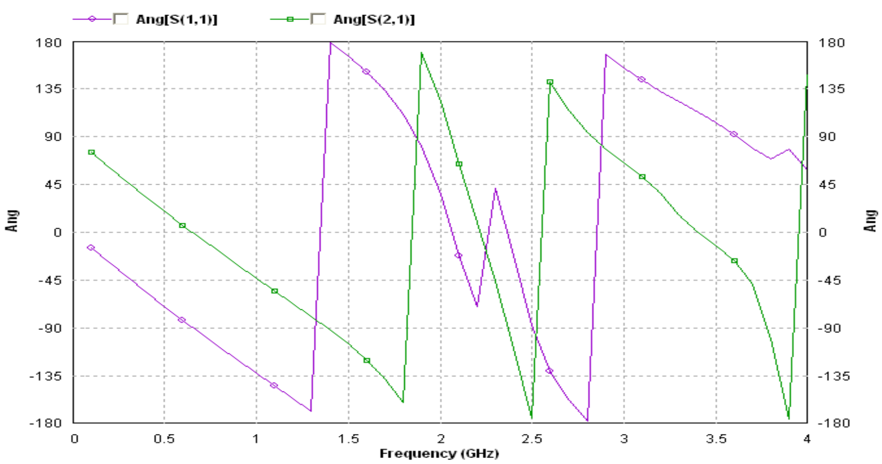

Figure 9: Phase response of the proposed structure

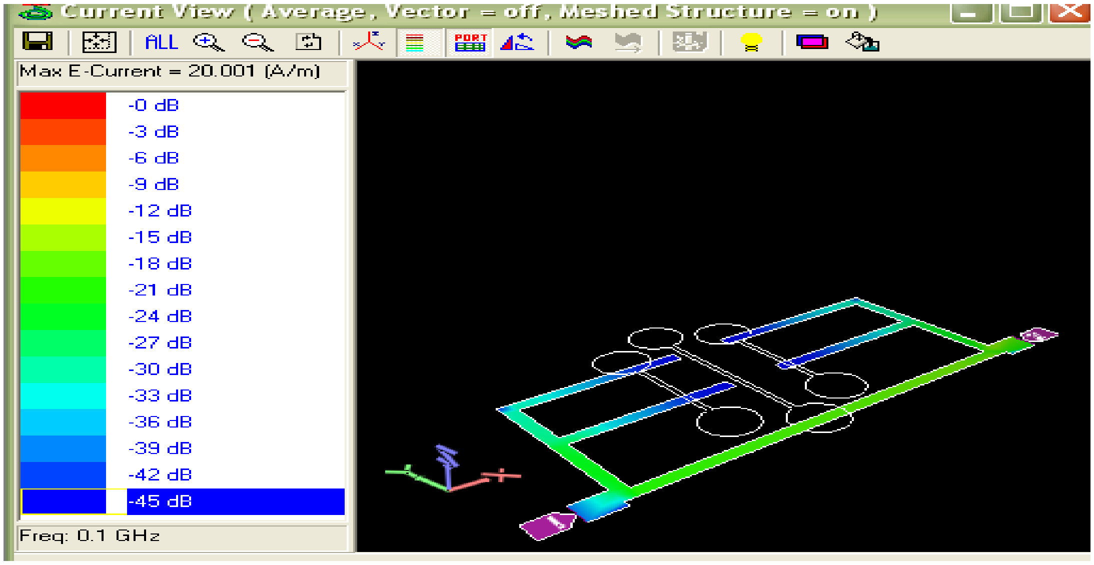

Figure 10: Current distribution in the proposed microstrip band reject filter

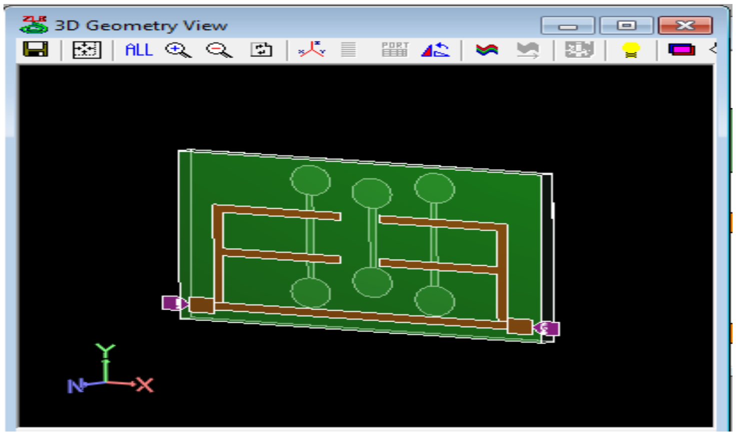

Figure 11: 3-D View of the proposed filter structure

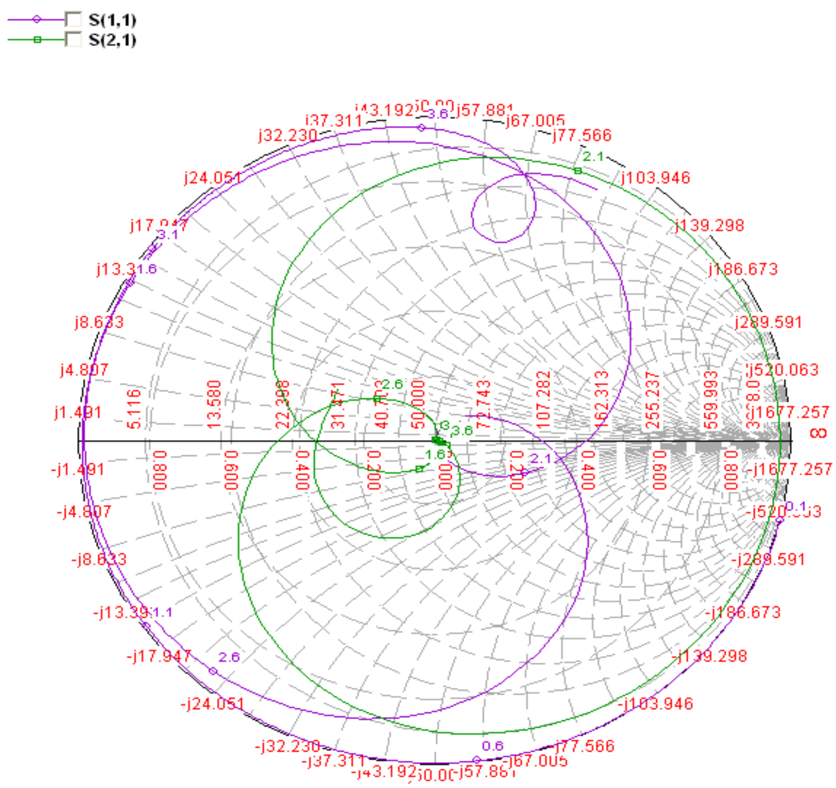

Figure 12: Smith Chart of the proposed design

4. Conclusion

1.61 GHz is the mid stop-band frequency of proposed microstrip band reject filter structure used for Radar, satellite and other S-band applications. The band elimination filter characteristics, return loss, insertion lass, sharp-cut-off achieved through DGS structure of filter. Mathematical modeling is used for calculation of filter dimensions and fabrication of prototype. Prototype has very less size, high insertion loss, sharp cutoff and low return loss at the resonant frequency which is the preferred performance of an ideal microstrip band elimination filter. More innovative microstrip filter, antenna topologies will be designed using defected microstrip structure for other band of applications in future prospects.

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