International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-05, Issue-01, April 2019

Full mode SIW Bandpass Filter for C-band Radar Application Using Defected Ground Structure

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Abstract – In this paper a novel design of full mode substrate integrated waveguide bandpass filter using defected ground structure is designed. Using the defected ground structure concept, a new class of SIW BPF is designed to improve the stopband performance. U-shaped dumbbell is introduced in the groundplane of the SIW cavity to increase the out of band rejection. The dimensions of the DGS is further optimized to provide the resonant frequency of the filter. The microstrip line is fed into the SIW cavity over a material with dielectric constant of 3.5 and thickness of 0.5mm. The simulated results obtained from the proposed filter with insertion loss of 0dB, return loss >18dB and fractional bandwidth of 4.2%. The filter works with center frequency of 7.1GHz and the simulated parameters satisfy required limits hence making the proposed filter suitable for C-band radar applications.

***Keywords-** Substrate Integrated Waveguide(SIW), Bandpass filter(BPF), Defected ground structure(DGS), U-shaped dumbbell, radar application*

I. INTRODUCTION

RF, Microwave and millimeter wave circuits are highly demands in the modern wireless sensing and communication systems. A well-designed SIW based bandpass filter has the advantage of compact size, low loss, low insertion loss, power handling and low fabrication tolerances when compared with rectangular waveguides and other conventional waveguide filters. In fact rectangular waveguides provides low losses and god selectivity but their production cost is high and integrating with other planar circuits requires a specific transition. In [1], substrate integrated waveguide based bandpass filter is designed with circular inductive posts is presented. As the SIW bandpass filters combined with planar resonators, their phase shift characteristics are used to obtain the desired coupling between the SIW cavities and microstrip resonators[4]. High performance, smaller footprint and low insertion loss can be obtained using air as dielectric instead of using dielectric material hence called air filled SIW(AFSIW)[3] . Using one side via hole technique called half mode substrate integrated waveguide(HMSIW), which exhibits passband characteristics and propagation characteristics of the filter. It is also used to achieve the slow wave effects[4-5]. A new technique known as defected ground structure is introduced, hence microstrip filters designed with the DGS is further to improve the filter performance[6]. Upper stopband performance and high selectivity is provided by the use of DGS slots or defects in the ground palne[7]. Another method of using UWB BPF with notch band further to provide wide passband and stopband bandwidth[8].

This paper presents the full mode SIW bandpass filter using defected ground structure is proposed. The DGS used here is U-shaped dumbbell is etched on the bottom ground plane of the SIW cavity in order to improve the stopband performance of the filter. The dimensions of the DGS are optimized to obtain filter resonant frequency. The microstrip to SIW transition is used to avoid radiation losses between the SIW cavity and the microstrip line. The proposed filter is designed and simulated using EM simulation called Advanced Design Software(ADS) and the proposed filter is suitable for the C-band radar applications.

II. THEORY AND ANALYSIS

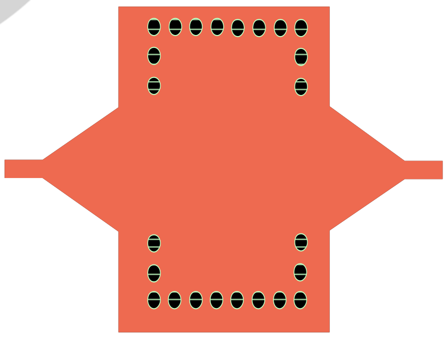


Figure.1 Structure of SIW

SIW structure consists of copper plane, substrate layer and ground plane. Metallic via holes are etched on the edge of the SIW cavity in parallel position. The resonant frequency of the SIW cavity TE_{m0n} mode can be calculated as,

$$f_{m0n} = \frac{c_0}{2\sqrt{\epsilon_r}}\sqrt{\left(\frac{m}{a}\right)^2 - \left(\frac{n}{l}\right)^2} \quad (1)$$

ISSN : 2454-9150 Vol-05, Issue-01, April 2019

Where c_0 is the speed of the electromagnetic waves in vacuum and ϵ_r is the relative dielectric constant. The parameters to be considered are W_{SIW} is the SIW, L_{SIW} is the length of the SIW, W_m is the width of microstrip line, L_m is the length of the microstrip line, D is the diameter of the via hole, and P is the post spacing. The propagation properties are similar for both SIW and conventional waveguides. Generally tapering has to be done between the microstrip line and SIW cavity. The tapered transition is used to provide impedance matching between planar transmission line and SIW structure.

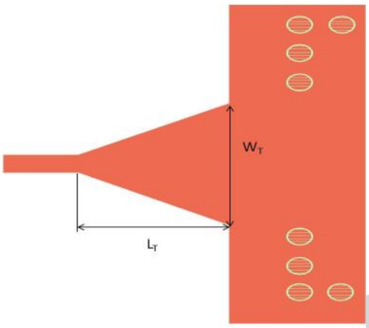
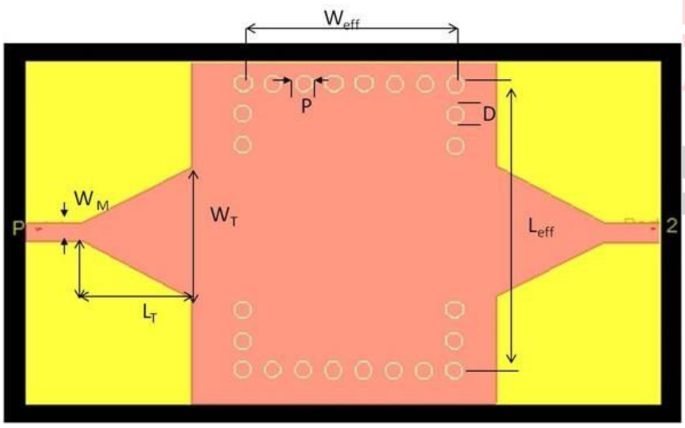


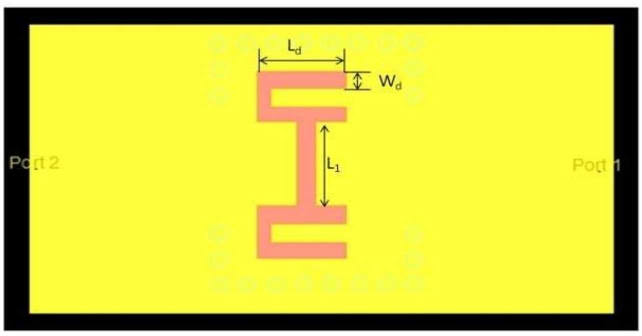
Figure.2 Tapered via transition

The electromagnetic energy distributes at the center of the SIW cavity, which results in avoiding radiation losses with improved quality factor. Compared with conventional microstrip resonators the proposed filter structure has lower insertion loss and better transmission performance.

III. DESIGN OF PROPOSED SIW BPF

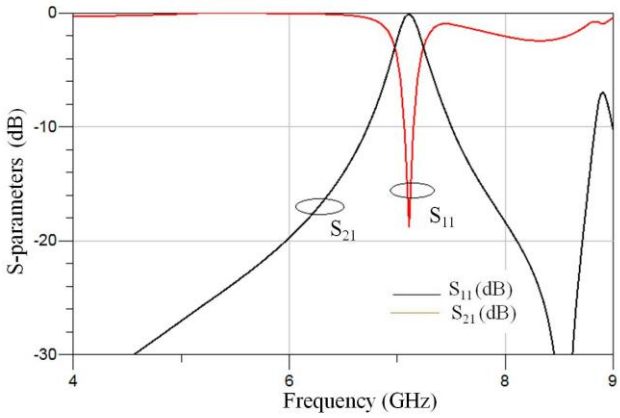


(a)



(b)

The dimensions of the filter are L_{eff}=13.5mm,W_{eff}=9.7mm,W_{d}=1mm ,L_d=4.5m, d=0.8mm,P=1.3mm, W_T =6mm, L_1=4.5mm.



(c)

Figure.3 Structure of the proposed SIW BPF

(a). Top view (b). Bottom view (c). Simulated frequency response of the filter

Fig.3 shows the layout of the proposed SIW bandpass filter. The structure has the top metal plane, substrate and bottom ground plane. The substrate here used is the Rogers with thickness of 0.5mm and dielectric constant of 3.5mm. The microstrip transition is used to interconnect SIW and the planar transmission line. The SIW cavity is tapered via transition to provide proper matching between the microstrip line and SIW cavity. The defected ground structure is made by etching U-shaped dumbbell on the bottom ground plane to improve the upper stopband attenuation. The DGS is etched on the center of the ground plane so that the field current distribution concentrated towards center of the SIW cavity. Further optimization can be done by varying the dimensions of the etched part.

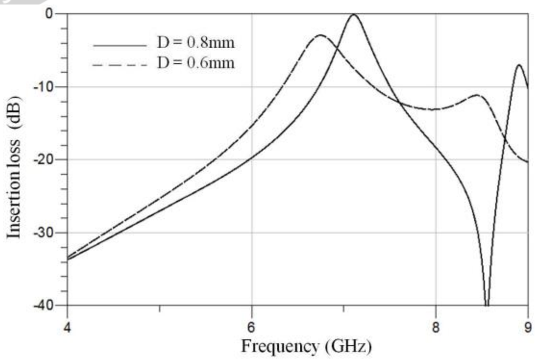


Figure.4 Simulated S_{21}(dB) for different via diameter

DOI : 10.18231/2454-9150.2019.0265

ISSN : 2454-9150 Vol-05, Issue-01, April 2019

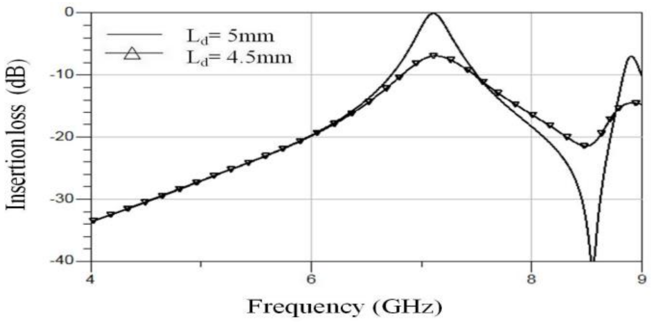
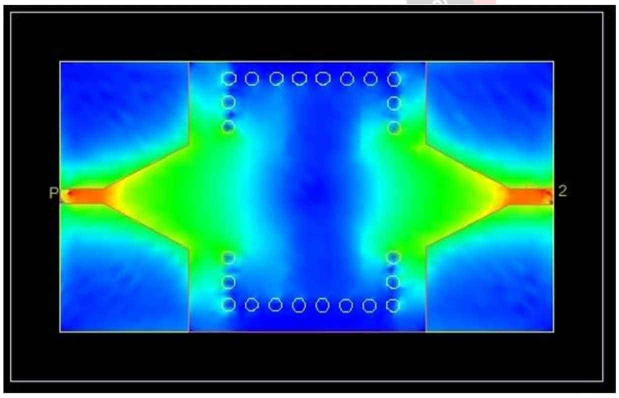


Figure.5 Simulated insertion loss of the filter by varying length L_d

Fig.4 shows the simulated S_{21} of the proposed filter for different via diameter. It can be seen that by increasing the via diameter the insertion loss and upper stopband attenuation gets improved. In fig.5 under coupling can be avoided by increasing the DGS slot length thus by increasing the etched slot length the stopband performance of the filter is incresed.

IV. SIMULATED RESULTS

The full mode SIW bandpass filter with U-shaped dumbbell DGS on the ground plane with size of 29mm×16mm. The SIW via transition is used to avoid the radiation and leakage losses. The dimensions of the U-shaped dumbbell DGS is optimized to obtain the stopband attenuation and filter to operate at the center frequency of 7.10GHz. The proposed filter shows the simulated results has return loss -18dB, insertion loss of 0dB with fractional bandwidth of 4.2%. The filter is simulated using Advanced Design Software(ADS).



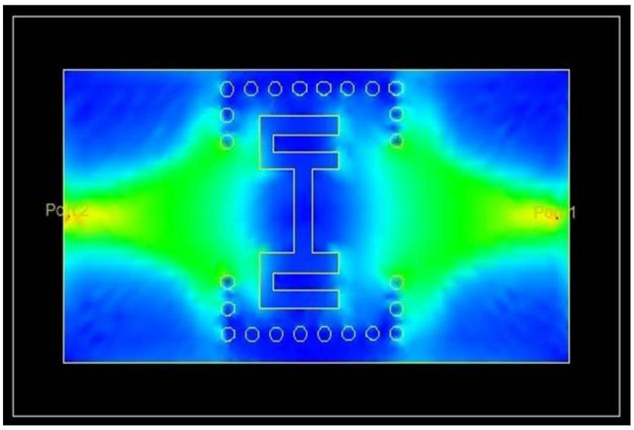


Figure.6 Field Current Distribution

V. CONCLUSION

In this work, SIW bandpass filter with U-shaped dumbbell DGS etched on the ground plane is realized. The filter is optimize to operate with the center frequency of 7.10GHz which is suitable for C-band radar application. The proposed filter has the advantage of compact size, low insertion loss, good return loss with improved bandstop performance.

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