Ka band compact and high performance SIW bandpass filter based on defected ground structure(DGS)

[1]Banu priya A, [2s]Umma Habiba H
[1]PH.d scholar, [2]Professor
Department of Electronics and Communication Engineering, Sri Venkateswara College of Engineering, Anna University, Sriperumbudur, Tamil Nadu 602117, India

Abstract :This research work proposes a novel bandpass filter using substrate integrated waveguide(SIW). Based on the concept of defected ground structure(DGS), a new class of SIW bandpass filter is designed in order to increase the out of band rejection. The proposed filter is designed by etching circular dumbbell shaped DGS in the ground plane of the SIW cavity and it is analyzed for different dimensions to obtain the desired filter response. The filter is fed using microstrip to SIW transition technique over a material with dielectric constant of 3.5 and thickness of 0.5mm. Utilizing this concept, SIW bandpass filter of center frequency 29.7GHZ with fractional bandwidth of 3.3%.The simulated results obtained with insertion loss of 1.7dB, return loss >20dB. The structure has been designed and simulated using Advanced Design Software(ADS).

Index Terms—Bandpass filter, Defected ground structure(DGS), Substrate integrated waveguide(SIW), Circular dumbbell DGS(DB-DGS), Fixed satellite services(FSS)

I. INTRODUCTION

Microwave and millimeter-wave communication systems influences the high-demand in modern wireless communication systems. SIW which is based on planar dielectric substrate provides a compact size, low-cost, sharp selectivity and low insertion loss for integrating active circuits, passive components and radiating elements on the same substrate. Substrate integrated Waveguide can also integrate an advantage of both uniplanar rectangular waveguide and planar microstrip transmission line than the waveguides which has high ohmic losses. An SIW rectangular cavity loaded with CSRR by triple mode filter provides frequency response, out of band rejection and skirt selectivity(1). A smooth transition is provided by using tapered via transition from microstrip line(planar structure) to SIW cavity with minimal reflection and has wider bandwidth(2). In (3), bandpass characteristic of SIW filter can be obtained by using single and multiple inductive posts in

substrate integrated cavity. Another emerging technique for improving the upper stopband performance and provides high selectivity by using Slots or defects integrated on the ground plane of microwave planar circuits are referred to as Defected Ground Structure(DGS)(4). In (5) SIW cavity is loaded with three different DGS patterns to operate waveguide below cutoff frequency. By using the unique resonant properties of CSRR and a pair of dumbbell DGS(6), two passbands with transmission zero in the middle have been achieved. In (7), Microstrip filters also designed by loading dumbbell DGS(DB-DGS) on metal strips . Another method of providing wide passband and stopband bandwidth by using UWB BPF with notched band(8).

Based on the different shapes of dumbbell DGS(DB-DGS), a novel SIW bandpass filter with much compact size and narrow passband can be obtained by combining the SIW structure with defected ground structure(DGS). The filter is designed by etching the circular dumbbell DGS in the ground plane of the SIW cavity to improve the stopband characteristics. The proposed SIW filter with DB-DGS used to obtain the bandpass filtering response which is usable to the

II. DESIGN AND ANALYSIS

2.1 SIW BANDPASS FILTER DESIGN

SIW BPF is synthesized by array of metalized via holes connected upper and lower metal plates of dielectric substrate. The important parameters need to be considered are diameter of the metallic via holes d, spacing between the holes p, length of the microstrip transmission line L_m, width of the microstrip transmission line W_m, effective length of the SIW L_{eff} and effective width of the SIW W_{eff}. The SIW structure consists of SIW cavity, microstrip tapered transition and a 50Ωmicrostrip transmission line. The microstrip energy can be easily transformed to SIW by using planar tapered transition. The microstrip line connecting the SIW cavity has been tapered for proper impedance matching and this structure known as microstrip to SIW transition. The effective width and length of the SIW structures can be calculated by given formula

$$W_{eff} = W_{SIW} - \frac{d^2}{0.95p} \quad (2.1)$$

$$L_{eff} = L_{SIW} - \frac{d^2}{0.95p} \quad (2.2)$$

The resonant frequency of the desired passband can be given as

$$f_0 = \frac{c_0}{\epsilon_r}\sqrt{(\frac{1}{W_{eff}})^2 + (\frac{1}{L_{eff}})^2} \quad (2.3)$$

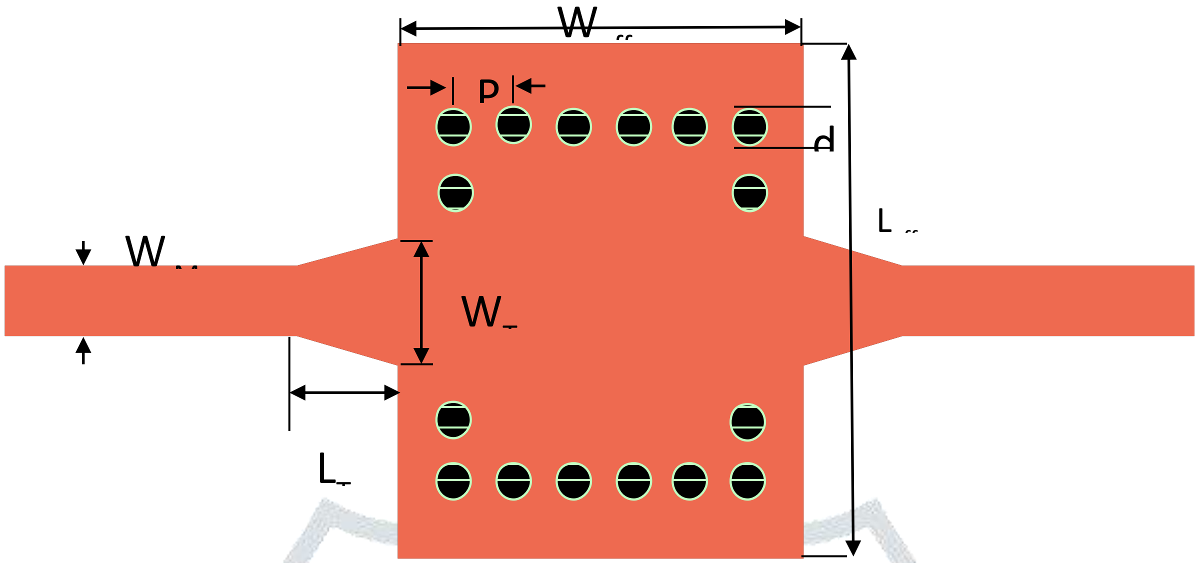

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Figure.1 Layout of the SIW BPF without DGS

The via spacing p must be kept small in order to avoid leakage losses between the adjacent vias, so the filter should satisfy the following conditions, d/p>0.5, $d/W_{SIW}<0.4$. According to this, the diameter of via hole is 0.4mm. In the conventional SIW BPF, DGS is introduced on the bottom ground plane to improve stopband performance.

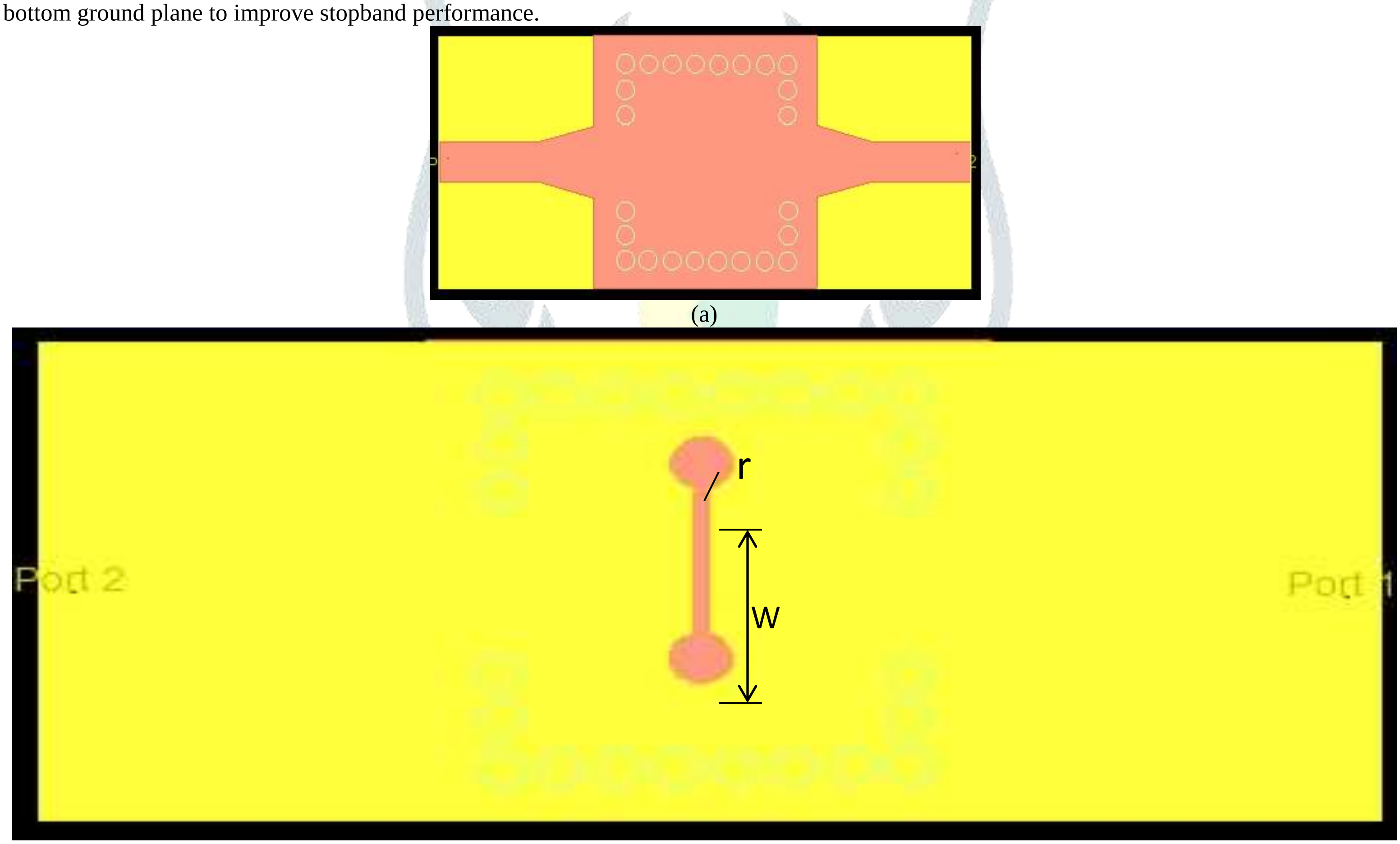

Figure.2 Proposed SIW BPF

(a) Top view (b) Bottom view

2.2 DESIGN OF SIW BPF WITH CIRCULAR DB-DGS

Fig.2 shows the layout of the proposed SIW BPF with circular dumbbell DGS. The SIW structure is designed by etching circular head DGS in the ground plane of the SIW cavity. The electric field is concentrated around the etched gap in ground plane of the SIW cavity. The DGS is used to create a transmission zero in order to increase the out of band rejection. OPtimization can be done by adding both horizontal and vertical rows of vias with diameter of 0.4mm. The proposed filter is developed on the Rogers substrate with dielectric constant of 3.5 and its thickness is

0.5mm. The filter is simulated using EM simulation software like Advanced Design System(ADS) to obtain S-parameters. Circular dumbbell DGS is introduced for fine tuning of the resonant frequency to achieve the filter performance.

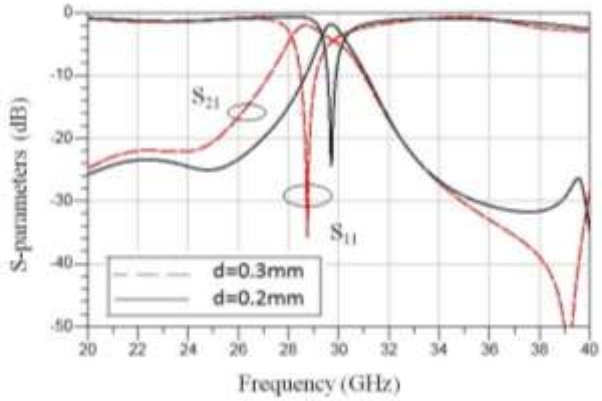

Figure.3 Simulated response of the SIW BPF for different via diameter

The dimensions of the filter are L_{eff}=5mm,W_{eff}=5.2mm,$W_{T=}$1.5mm,W_M=0.8m,L_T=1.2mm,d=0.4mm, P=0.75mm,W=1.3mm, r=.0.3mm.

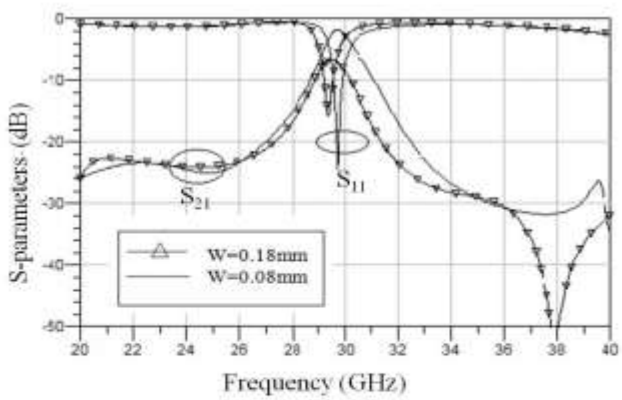

Figure.4 Simulated S-parameters of the proposed filter for varying W-values

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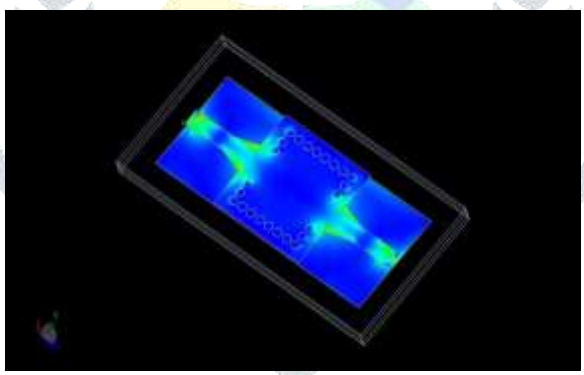
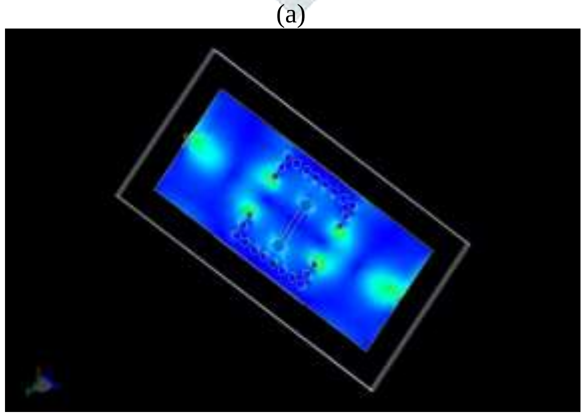


(a)



(b)

Figure.5 Surface current density of the filter

Fig.3 presents the simulated s-parameters of the SIW BPF with circular dumbbell DGS for different via diameter with center frequency of 29.7GHz and insertion loss of dB. By increasing the diameter of via the resonant frequency shifts towards lower frequency side with good return lossFig.4 shows the simulated response of the proposed filter for different width of the circular dumbbell DGS. It can be seen that under coupling in the filter insertion loss can be avoided and also there is an upper frequency shift occurs by reducing the width of the DGS slot.

III. RESULTS AND DISCUSSION

The proposed filter is realized on the Rogers substrate. The filter has total size of 11mm×5mm including input/output tapered microstrip lines. The 50Ω microstrip transmission lines are widely used to produce narrow bandwidth in SIW filter design. The simulated results with center frequency of 29.7GHz,has insertion loss of 1.7dB, return loss of >20dB with 3-dB bandwidth of 3.3% and stopband attenuation is over 30dB/decade.

IV. CONCLUSION

A compact and high performance full mode SIW BPF using circular dumbbell DGS(DB-DGS) is designed and simulated. The filter with center frequency of 29.7GHz and it is applicable for Ka band applications and fixed satellite services(FSS). The proposed filter possesses better stopband characteristics due to the presence of Circular head dumbbell DGS in the SIW structure. The proposed full mode SIW BPF design has the advantage of low loss, compactness and better out of band rejection.

References

1. Zheng Liu,Gaobiao Xiao,Lei Zhu, "Triple mode bandpass filteron CSRR loaded substrate integrated waveguide cavities", *IEEE Transactions on components, packaging and manufacturing technology*, vol.6,No.7, pp 1101-1107, July 2016.
2. Chandra Sekhar Panda, Rashmiranjan Nayak, Santanu Kumar Behera, "Design and Analysis of a Compact Substrate Integrated Waveguide Bandpass Filter for Ku Band Applications", IEEE, 978-1-5090-4556-3/16. 2016.
3. Sourav Moitra, Basudeb Mondal, Jhuma Kundu, Asish Kumar Mukhopadhyay and Anup Kumar Bhattacharjee, "substrate integrated waveguide (siw) filter using stepped-inductive posts for ku-band applications", IET,2013.
4. Mukesh Kumar Khandelwal, Binod Kumar Kanaujia, and Sachin Kumar. "Defected Ground Structure: Fundamentals, Analysis, and Applications in Modern Wireless Trends", *Hindawi International Journal of Antennas and Propagation*, Volume 2017, Article ID 2018527, 22 pages, February 2017.
5. Huang Y.M., Shao Z., You C.J., ET AL.: 'Size-reduced bandpass filters using quarter-mode substrate integrated waveguide loaded with different defected ground structure patterns', IEEE, 978-1-4799-8275-2/15, 2015.
6. Weiping Li, Zongxi Tang, and Xin Cao**, "**Design of a SIW Bandpass Filter Using Defected Ground Structure with CSRRs", *Hindawi Active and Passive Electronic Components*, Volume 2017, Article ID 1606341, 6 pages, January 2017
7. Arjun kumar, M.V.Karthikeyan, "Design and realization of microstrip filters with defected ground structures(DGS)", *International journal on engineering science and technology,* pp 679-686, November 2016.
8. H.Chu, X.Q.Shi, "Compact ultra wide band bandpass filterbased on SIW and DGS technology with a notch band", *Journal of electromagnetic waves and application*,vol.25,pp 589-596,April 2012.