DESIGN AND ANALYSIS OF FULL MODE SIW BANDPASS FILTER FOR 5G APPLICATIONS

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Abstract: In this paper a millimeter-wave(mmW) narrow bandpass filter is proposed and designed by using substrate integrated waveguide(SIW) by using T-shape slot. The stopband performance is achieved by using DGS which is etched on the ground plane of the SIW cavity. The DGS has been analyzed for different dimensions of T-slot to achieve the good stopband performance.. The proposed structure has been designed over a dielectric substrate with dielectric constant of 3.5 and with thickness of 0.5mm. The SIW bandpass filter achieves an insertion loss of 1.2dB, and a return loss of better than 25dB. The proposed filter has a pass-band covers 26.5GHz to 27.5GHz and its fractional bandwidth is about 3.7%. The proposed filter is designed and simulated using ADS(Advanced Design System) software.

***Index Terms*—Bandpass filter, Defected ground structure(DGS), Substrate integrated waveguide(SIW), T-shaped slot, Fixed wireless access(FWA)**

I.Introduction

Nowadays, the quick development of the high-performance of microwave and millimeter-wave communication systems influences the high-demand of this technology. SIW which is based on planar dielectric substrates with top and bottom metal layers perforated with metalized holes. It 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.

SIW, as a new means of signal transmission, have been the basis for the design of many circuit components. It is low cost realization of the traditional waveguide circuit for microwave and millimeter-wave applications. It inherits the merits from both the traditional microstrip for easy integration and the waveguide for low radiation loss. In such a circuit, metallic post are embedded into a printed circuit board, which is covered with conducting sheets on both side, to emulate the vertical walls of a traditional waveguide. Hybrid cavity with the combination of both circular and rectangular cavity shows better frequency selectivity and Q-factor(1).. In (2) various microstrip filters are designed with new metal strips loaded defected ground structure(DGS) with conventional dumbbell-shaped DGS(DB-DGS).An SIW rectangular cavity loaded with CSRR by triple mode filter provides frequency response, out of band rejection and skirt selectivity(3). Elliptic lowpass filter using DGS improves slow wave factor and power handling capacity, Due to this the filter is more compact and reliable than conventional filters(4). The SIW loaded by novel DGS supports evanescent mode wave propagation below the cutoff frequency of SIW achieves two transmission poles at the passband(5). Microstrip U-shaped DGS resonators are proposed to suppress the harmonic response(6). To improve the performance of the filter like passband ripple, 3-dB bandwidth, return loss and stopband rejection by using defected ground structure(7). A compact dual band BPF SIW filter using DGS resonators are used to achieve better frequency selectivity and wide stopband performance(8). Another method of providing wide passband and stopband bandwidth by using UWB BPF with notched band(9).

In this paper, narrow band full-mode SIW BPF is designed and analysed by introducing T-shaped slot. The proposed SIW filter with T-shaped slot has compact size, high frequency selectivity with better stopband attenuation and it is applicable for fixed wireless access systems.

II. Design and analysis

2.1 Principle of SIW filter

Conventional SIW BPF is designed by array of metalized via holes connected upper and lower metal plates of dielectric substrate. 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.

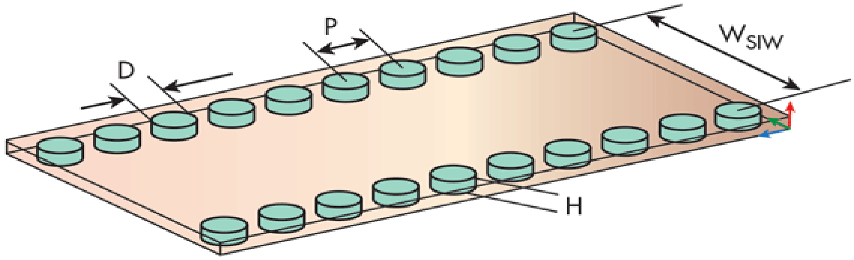


Fig.1 Structure of SIW

The microstrip line connecting the SIW cavity has been tapered for proper impedance matching and this structure known as microstrip to SIW transition. The above geometrical parameters derives significant role in designing SIW filter. P is the distance between center to center via on both rows, d is the diameter of the vias. W_{SIW} is the width of SIW, W_{eff} is the effective width of SIW, L_{SIW} is the length of the SIW, L_{eff} is the effective length of SIW. In order to avoid the leakage loss for via post in SIW cavity side walls, the filter should satisfy the following conditions,

$d/p>0.5$………………………………………………………..(1)

$d/W_{SIW}<0.4$……………………………………………………(2)

The mathematical equation for calculating the effective width and length is given by,

$W_{eff} = W_{SIW} - \frac{d^2}{0.95p}$ ………………………………………..(3)

$L_{eff} = L_{SIW} - \frac{d^2}{0.95p}$ …………………………………………(4)

Depending on the effective width of the SIW, the cutoff frequency can be calculated.

$f_c = \frac{c}{2w_{SIW}\sqrt{\varepsilon_r}}$ ………………………………………………..(5)

where 'c' is the speed of light. The impedance matching can be obtained by tapering between the SIW cavity and microstrip line.

2.2 Design of full-mode SIW BPF with DGS

Figure.3 shows the proposed SIW BPF with defected ground structure(DGS). The conventional SIW structure consists of T-shaped slot etched on the ground plane of the SIW cavity to improve the stop band performance. The structure is developed on the Rogers substrate that has a relative permittivity of 3.5mm and a thickness of 0.5mm . The filter is simulated to obtain S-parameters by using EM simulation software like Advanced Design System(ADS). T-shaped DGS is introduced for fine tuning of resonance frequency to achieve the filter performance. The filter is realized by modifying the dimensions in the structure's size.

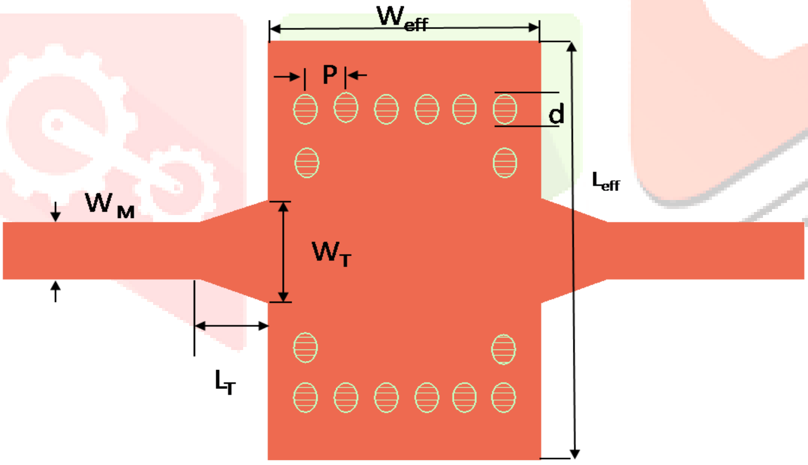
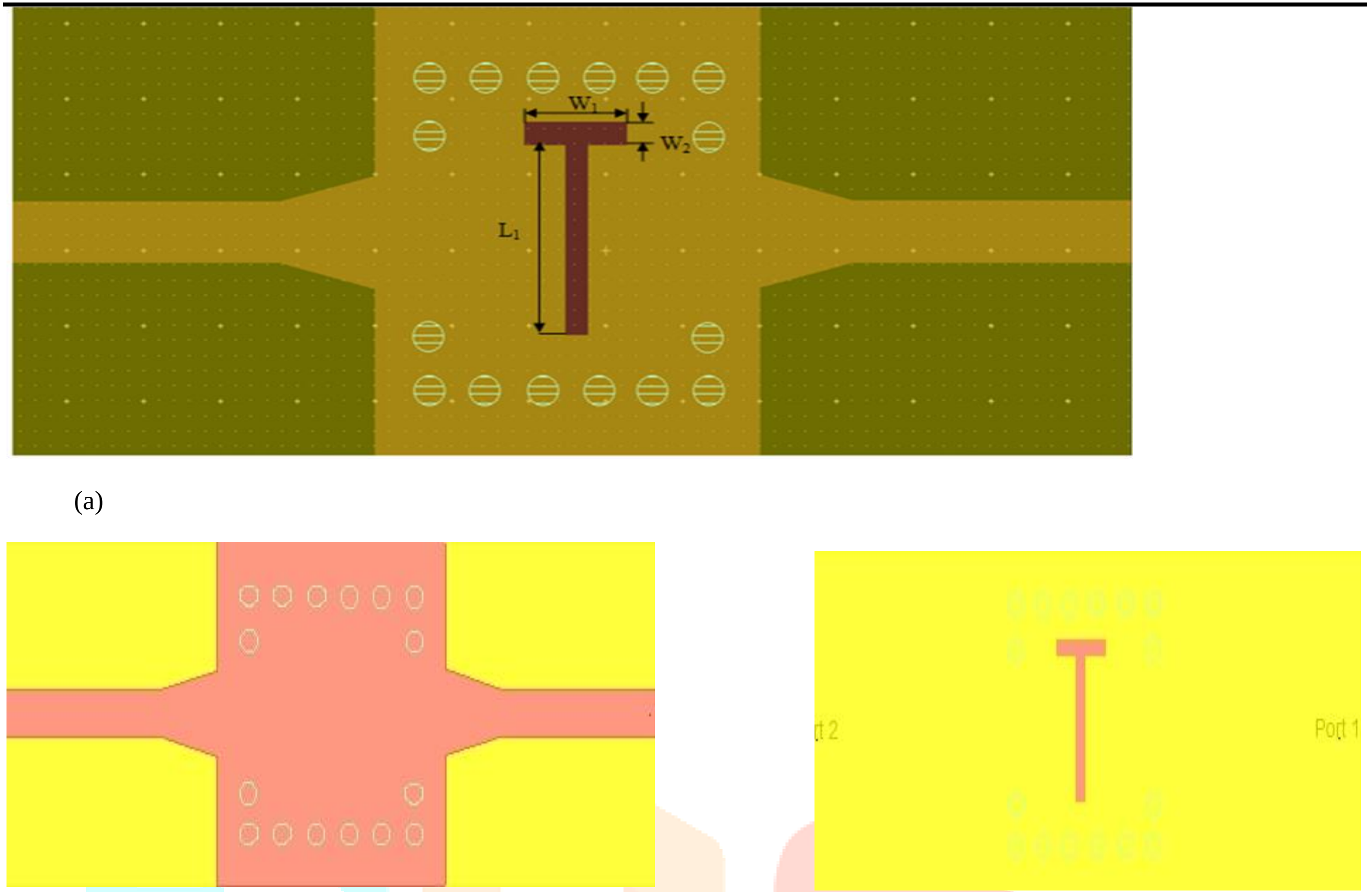


Fig.2 Full-mode SIW BPF without DGS

The filter dimensions are L_{eff} =6mm, W_{eff} =5mm, W_T=1.5mm,W_M=0.8m, L_T=1.2mm,d=0.4mm,P=0.75mm,W_1=1.3mm, W2=0.8.30mm,L_1=2.5mm.



(a)

(b)

(c)

Fig.3 Full-mode SIW BPF at 27GHz

a. Layout of the proposed full-mode SIW BPF b. Front view c. Back view

The frequency response of the full-mode SIW BPF with defected ground structure is shown in figure.4. The electric field is concentrated mostly around the etched gap in DGS. Full-mode SIW BPF is realized by tuning the dimensions of the T-slot. It can be seen that the circuit simulation enhances the characteristics of T-slot shape DGS. The proposed filter layout with T-shaped DGS improves the filter performance and provides passband frequency which is used for the future trends in 5G spectrum bands.

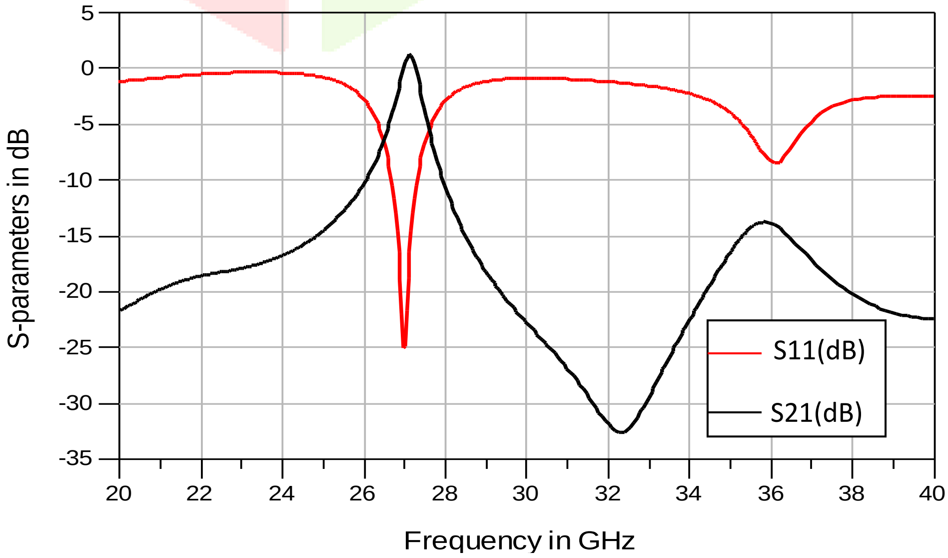


Fig.4 Frequency response of full-mode SIW BPF with DGS

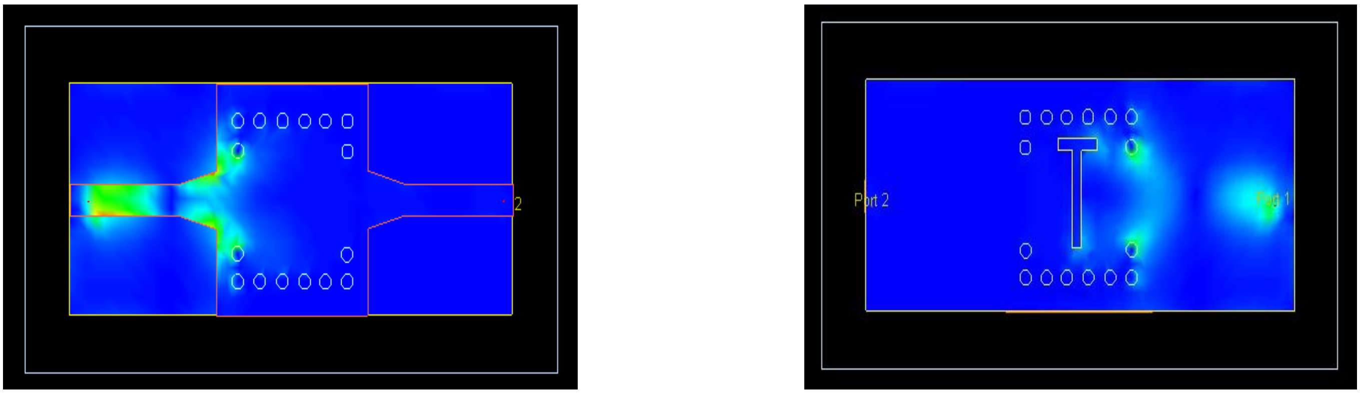


Fig.5 Surface current density of the filter

III. Results and discussions

A narrow band SIW BPF was designed and simulated using T-shaped slot as shown in figure.3&. The simulated S parameters shows 1.2dB insertion loss and better than 25dB return loss in the pass band with 3-dB bandwidth of 3.7%. we can observe that proposed filter has advantage of compact size, better return loss and lower insertion loss.

IV. Conclusion

In this paper, full-mode SIW BPF is designed with T-shaped DGS slot etched on the ground plane of SIW cavity to improve the stopband performance. The simulated results shows the passband bandwidth of 26.5GHz-27.5GHz with 3-dB bandwidth of 3.7% and applicable for future 5G spectrum bands and fixed wireless access(FWA). The proposed filter structure is simple, compact and better stopband performance.

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