A Ku-Band Compact Bandpass Substrate Integrated Waveguide Filter using L-shaped Slots

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Abstract

In this paper a compact substrate integrated waveguide (SIW) based bandpass filter using L-shaped slots for Ku-band application is proposed. First, the proposed filter structure has been analyzed by etching simple L-shaped slots on the top and bottom plane of the SIW cavity to obtain bandpass characteristics. Two SIW filter having varying passband from 15.94GHz to 17.08GHz depending on the slots on the top and bottom of the substrate having height of 0.5mm using periodically arranged metallic via holes. Eventually, the filter using L-shaped slots etched on the top of the SIW cavity achieves a low insertion loss less than 0.2dB, in-band return loss better than 40dB with fractional bandwidth of 6.9% at 16.46GHz. The proposed fitler has been simulated using Advanced Design System (ADS).

Keywords: *Bandpass filter (BPF), Substrate Integrated Waveguide (SIW), Defected Ground Structure (DGS), Defected Microstrip Structure (DMS), L-shaped Slot, Ku-band application.*

1. Introduction

RF, microwave and millimeter wave circuits uses microstrip components for their attractive features such as low cost, small size, easy fabrication, and easy integration with other circuits. Recently, there has been increased interest towards substrate integrated waveguide based circuit devices due to its high frequency characteristics. Among these a multilayer air filled SIW circuits have been used for substantial reduction in filter's insertion loss, which also exhibit larger footprint when compared with dielectric filled counterparts [1]. In [2], high quality factor can be obtained by using empty substrate integrated coaxial line with center conductor suspended in air. In order to improve the stopband characteristics of the filter, a new technology called defected ground structure (DGS) is introduced. The DGS is etched on the top of the SIW cavity to keep the filter performance with high accuracy [3-4]. In [5], four DGS resonators are etched on the bottom ground plane to achieve high performance and wider stopband. A new method of providing simple design, size miniaturization and good performance control by using defected microstrip structure (DMS) is introduced and analyzed [6]. Dual frequency operation is obtained by loading top layer of SIW cavity with two CSRRs, four transmission zeros are introduced to improve the selectivity [7-8]. LTCC based SIW bandpass filter with two antisymmetric U-shaped slots connected by via to construct negative coupling structure with superior frequency selectivity [9]. In [10], two pairs of dumbbell shaped slots etched on both top and bottom of the SIW cavity, which acts as a shunt resonators to reduce the filter size.

This paper presents the design of substrate integrated waveguide bandpass filter using L-shaped slots is designed and analyzed. Two SIW bandpass filter structure has been realized by etching L-shaped slots on the top and bottom metal planes of the SIW cavity to achieve bandpass characteristics of the filter, which is usable for Ku-band applications.

2. SIW Filter Design

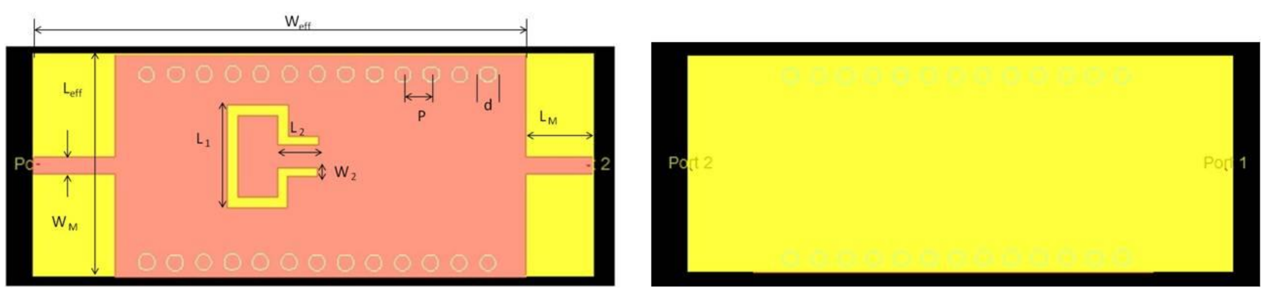
SIW filter is a planar dielectric filled waveguide and it is designed by array of metallic via holes connecting the upper and lower metal plates of the dielectric substrate. This array of via holes confines the electromagnetic field inside SIW structure. The parameters of the SIW filter are'd' is the diameter of the via hole, L_{eff} is the effective length of the SIW, a_s is the width of the SIW, 'p' is the distance between the via holes. The equivalent width is the effective width of the SIW and it can be obtained by a given relation,

$$a_{equi} = a - \frac{d^2}{0.95.p} \quad (1)$$

The cutoff frequency can be calculated by the(2), which depends on the width of the dielectric filled metallic waveguide a_s,

$$f_c = \frac{c}{2\epsilon_r W_{eff}} \quad (2)$$

Where C is the speed of the light and ϵ_r is the dielectric constant of the substrate. In this case, initially geometrical size of the SIW cavity can be designed by using equation (1).



(a) (b)

Figure.1 Layout of a SIW with L-shaped slot on the top of the substrate side

(a). Top layer (b). Bottom layer

The dimensions of the filter are L_{eff}=11mm, W_{eff}=20.3mm, L_M= 4mm, W_M=0.8m, L_1=0.5mm, d=0.8mm, P=1.4mm, W_2=0.4mm, L_2=2mm.

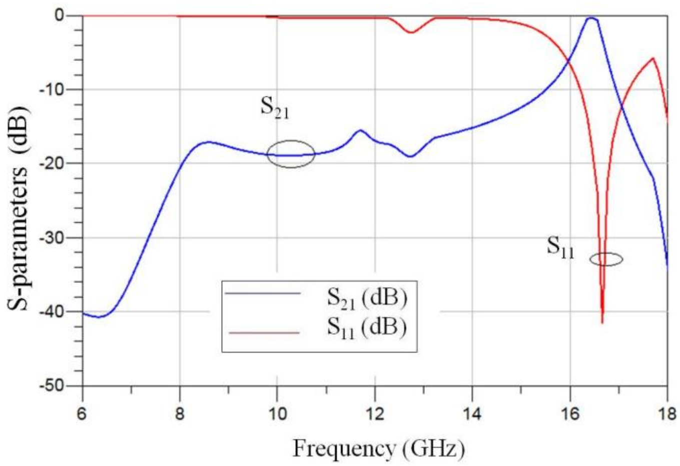
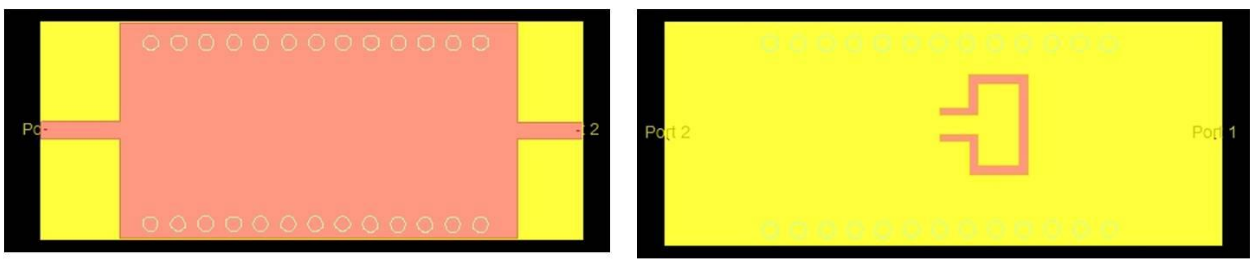


Figure.2 Simulated S- parameters of the filter with L-slots on top layer



(a) (b)

Figure.3 Layout of the SIW with L-slots etched on the bottom of the substrate

(a). Top layer (b). Bottom layer

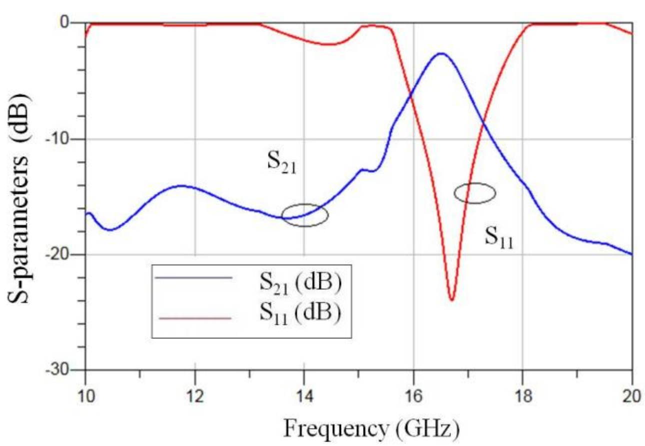


Figure.4 Simulated S-parameters of the filter with L-slots on bottom layer

3. L-shaped slot loaded SIW

Figure.1 shows the layout of the proposed filter with L-shaped slots etched on the top of the substrate layer. Figure.3 shows the layout of the filter with L-shaped slots on the bottom layer. Let us now analyze the L-slots loaded SIW. Since slots that are etched on the center of the top and bottom layer, the electric field is induced by the SIW cavity structure. First we analyze the L-slot loaded on the top of the SIW cavity. By etching the slot on the top layer of SIW, there is an increase in the upper stopband attenuation with lower insertion loss within the passband of the filter that is illustrated in figure.2. The SIW cavity with L-shaped slots defected on the bottom of the substrate and their frequency response shown in figure.4 demonstrates that there is an under coupling of the filter occurs with high insertion loss. By comparing both SIW structures, the filter with L-shaped slot etched on the top layer has lower insertion loss with improved stopband characteristics.

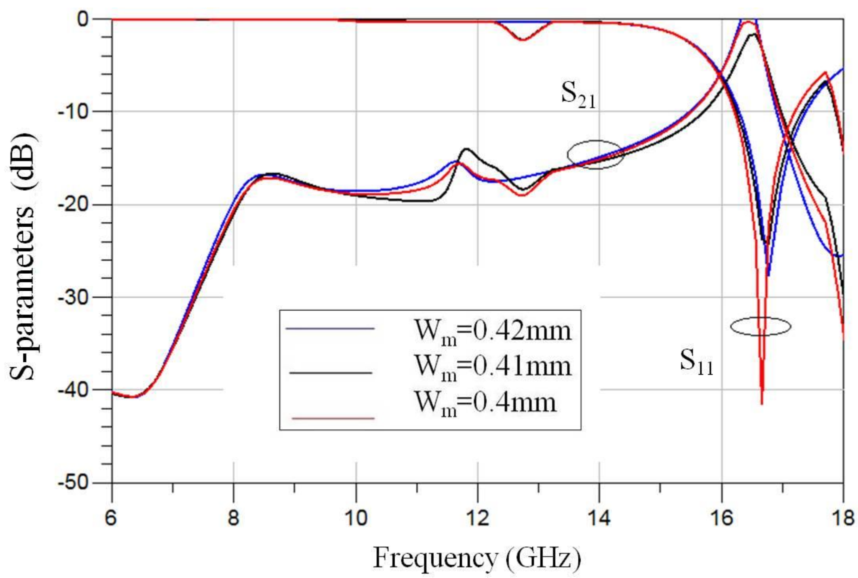


Figure.5 Frequency response of the filter with L-slots on the top layer with varying slot width

Figure. 5 shows the simulated frequency response of the SIW filter with L-slot etched on the top of the SIW cavity for different slot widths. It can be seen that by reducing the width of the L-slot, the in band insertion gets improved along with increase in the return loss of the filter. Figure.6 illustrates the frequency response of the filter with L-slot etched on the bottom of the substrate with varying width of the slot. It shows that resonant frequency moves downwards by reducing slot width. Consequently the lower attenuation gets improved with reduced slot width.

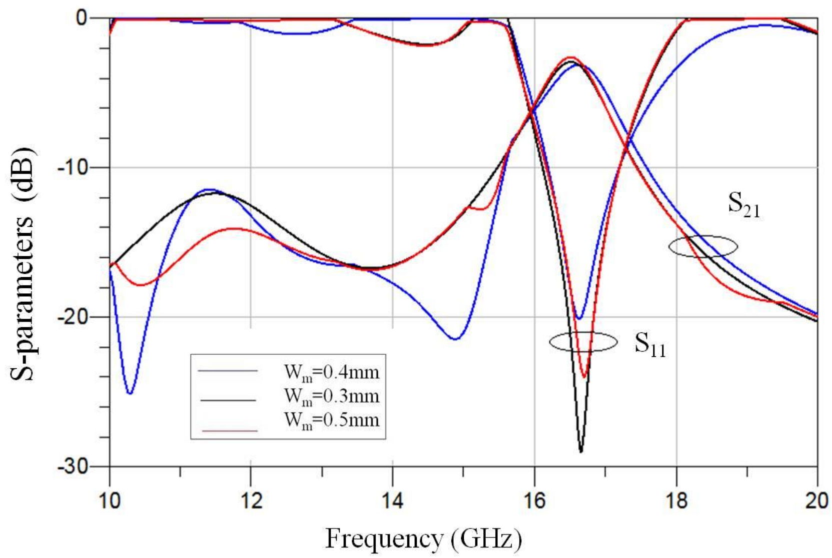
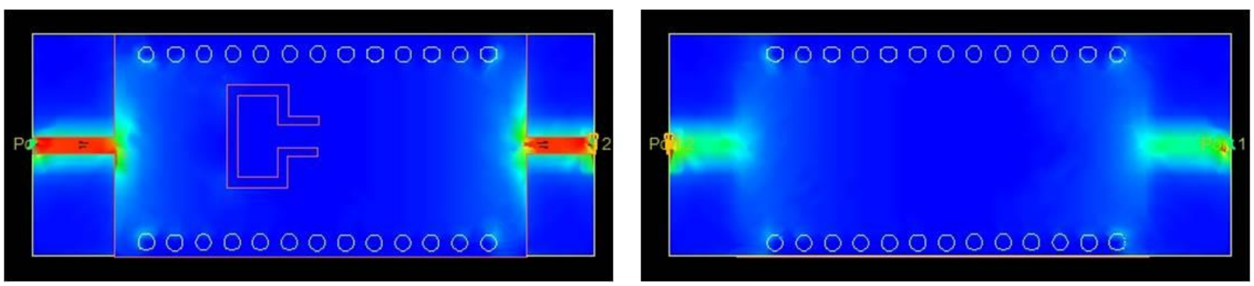
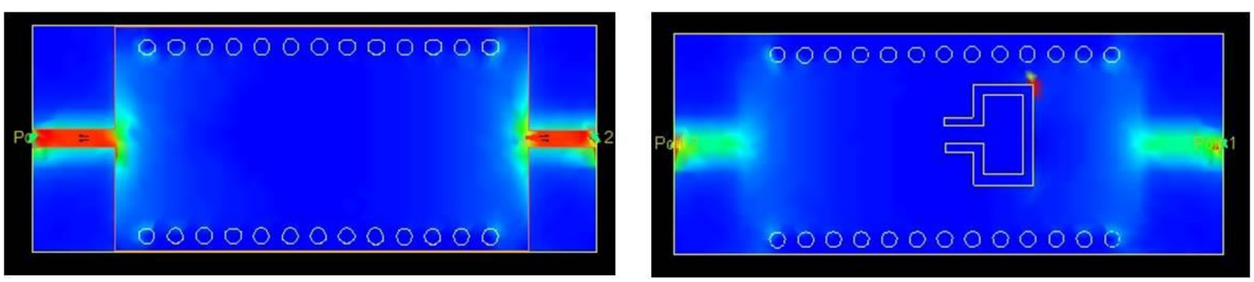


Figure.6 Frequency response of the filter with L-slot on bottom layer with varying slot width



(a)



(b)

Figure.7 Electromagnetic field distribution of the filter

(a). L-slot on top etched (b). L-slot on bottom etched

4. Simulated Results and Discussion

The proposed filter structure is developed on the Rogers substrate with thickness of 0.5mm and dielectric constant of 3.5 and the filter structure is simulated and analyzed using EM simulation (Advanced design system). The SIW filter structure with L-shaped slots etched on the bottom ground plane shows insertion loss of 2.6dB, return loss of 24dB with fractional bandwidth of 7.8% at 16.51GHz and passband in the range of 15.9GHz to 17.2GHz. Another filter structure with L-shaped slots etched on the top metal plane shows excellent filter characteristics with low insertion loss of 0.2dB,upper stopband attenuation of >30dB, return loss of 41.5dB at center frequency of 16.46GHz.

5. Conclusion

Two different SIW bandpass filter structure designed at 16.5GHz are discussed in this paper. First the filter is designed with L-shaped slots etched on the top of the SIW cavity. Second the filter structure is designed by L-shaped DGS etched on the bottom ground plane without any slot on the top conducting plane. The simulated results are compared and it was found that performance of the SIW bandpass improved with the use of slot etched on the top metal plane. Eventually the filter structure with L-slot on the top metal plane having very low insertion loss, good return loss and also upper stopband performance has been improved. The proposed filter structure operating at center frequency of 16.5GHz and it can be used for Ku-band applications.

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