Design and Analysis of SIW Bandstop Filters for Interference Suppression in X Band

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***Abstract*—In this paper, six different bandstop filter designs using Substrate Integrated Waveguide (SIW) resonator coupled to microstrip transmission line is presented. A curved and rectangular SIW resonator was designed and then coupled to microstrip transmission line to provide a band reject response in Advanced Design System Momentum RF software. These filters were designed for interference suppression in X-band and simulated on Rogers RO4350 substrate with thickness of 0.508 mm and relative dielectric constant of 3.48. The simulated result was compared with other bandstop filter at X-band and showed a good suppression at 9 GHz region with attenuation of -61.9 dB and -3 dB bandwidth of 90 MHz.**

***Index Terms*—Bandstop Filter; Substrate Integrated Waveguide; Cavity Resonator; Interference Suppression; Curved Cavity; Waveguide; Cascaded; Coupled Resonator.**

I. INTRODUCTION

The most serious problem for dual mode radar is the occurrence of interference between tracking and searching radar [1]. A high Q with high level suppression bandstop filter is required to eliminate the unwanted signal. Such filter generally has characteristic of high insertion loss and increased Q-factor. The problems with conventional type bandstop filter is huge in size. Various design of bandstop filter has been study and proposed for application in X-band [1-8].

Bandstop filter (BSF) is widely used in almost all microwave systems for filtering out the unwanted signals and permitting good transmission of the desired signal. Ideal bandstop filters provide a high level of rejection over a limited bandwidth, while ideally exhibiting low passband loss so as to minimizing impact on the radar receiver sensitivity [2].

In this paper, a single and cascaded SIW resonator bandstop filter has been designed by directly couple the resonators to microstrip line using slot penetration. On the other hand, the coupled cascaded SIW resonator were couple to microstrip line and between both resonators using interdigital capacitor. SIW resonator has been design in rectangular and curved shape for comparison. A comparison to others SIW resonator bandstop filter design in filter response performance is also presented in this paper.

II. METHODOLOGY

A. SIW Bandstop Filters Design

The size of the substrate integrated waveguide cavity is determined by the corresponding resonance frequency. SIW structure is shown in Figure 1. Effective width of the SIW cavity W_{eff} can be determined [3] by:

$$f_{101} = \frac{c}{2\pi\sqrt{\mu_r \epsilon_r}} \cdot \sqrt{\left(\frac{\pi}{W_{eff}}\right)^2 + \left(\frac{\pi}{L_{eff}}\right)^2} \quad (1)$$

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

$$L_{eff} = L - \frac{d^2}{0.95 \cdot p} \quad (3)$$

where W is the width of the SIW cavity, L is the height of the SIW cavity, d is the diameter of the via holes, p *is* the spacing between via holes, and ϵ_r and μ_r is relative permittivity and relative permeability of the substrate respectively.

d and p can be determined by using a set of design rules for the substrate integrated waveguide [4] given as:

$$d < p < 2d \quad (4)$$

$$d < \lambda_g/5 \quad (5)$$

$$p/\lambda_c < 0.25 \quad (6)$$

where λ_g is the guided wavelength and λ_c is the cutoff wavelength.

The bandstop filters are designed to operate at X-band region. The effective width, W_{eff} obtained are 10 mm and effective length, L_{eff} are 20 mm with diameter of via holes, d of 0.8 mm and spacing between them, p is 1.7 mm. Figure 2 to Figure 4 shows the planar layout of the curved resonator bandstop filter and Figure 5 to Figure 7 shows the planar layout of the rectangular resonator bandstop filter of the proposed bandstop filter.

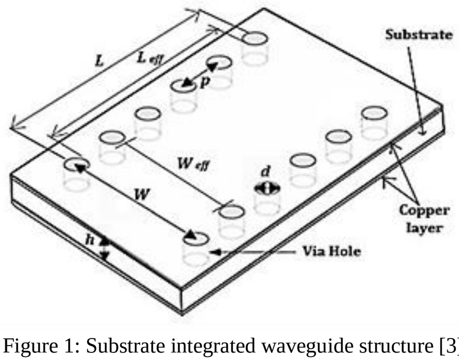

Figure 1: Substrate integrated waveguide structure [3]

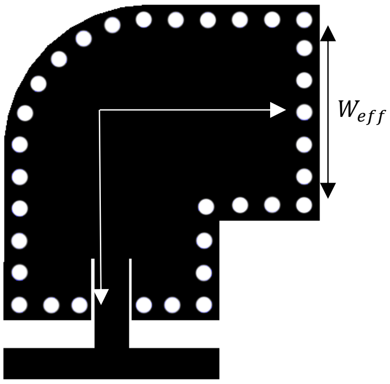

Figure 2: Configuration of single curved SIW resonator

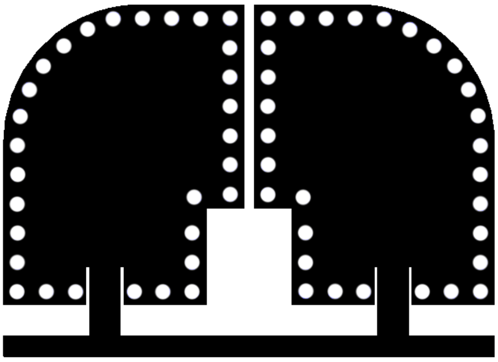

Figure 3: Configuration of cascaded curved SIW resonator

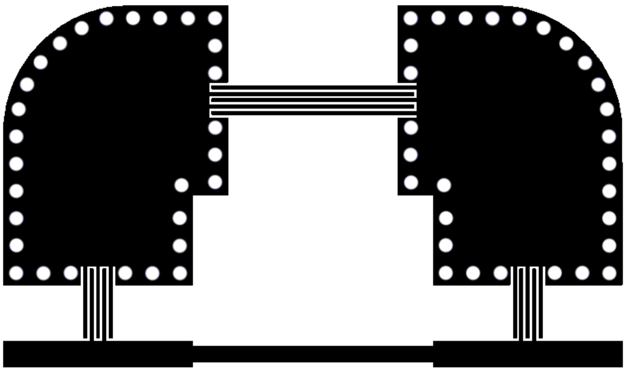

Figure 4: Configuration of coupled cascaded curved SIW resonator

Curved SIW resonator bandstop filter was designed based on previous work [5] which use different type of coupling on single and cascaded curve SIW resonator. This design has improved in bandstop filter response performance (bandwidth and return loss).

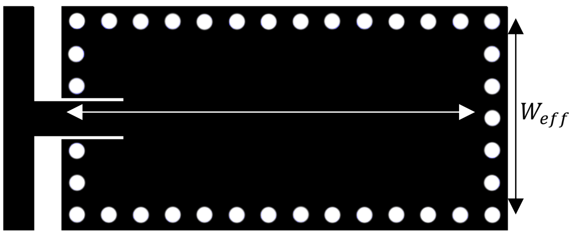

Figure 5: Configuration of single rectangular SIW resonator.

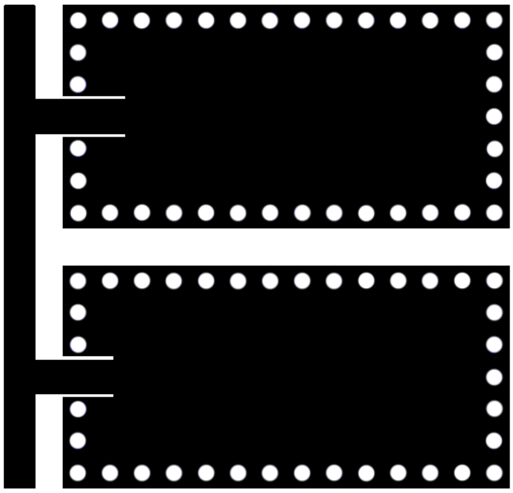

Figure 6: Configuration of cascaded rectangular SIW resonator

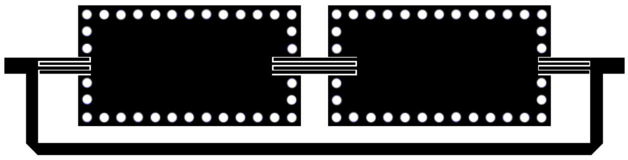

Figure 7: Configuration of coupled cascaded rectangular SIW resonator

For curved and rectangular, single and cascaded SIW resonator, a slot penetration was used. For coupled cascaded SIW, interdigital capacitor was used. Furthermore, only TE_{m0} modes is excited and extracted in the structure of SIW, thus, TM modes do not exist in the SIW structures [6]. The position of the slot penetration and interdigital capacitor coupling is located at the center of the width opening of the cavity to ensure only the TE_{10} mode was excited. The width and length of the slot penetration is 1.8 mm and 4.8 mm respectively with gap, 0.2 mm. The width of the interdigital capacitor fingers is 0.2 mm with gap, 0.2 mm between them.

III. Results and Discussion

A. Simulation Result

The EM simulation were accomplished using Advanced Design System Momentum RF software on RT/Duroid 4350 with the relative dielectric constant of 3.48, and the height of 0.508 mm. Figure-8 to Figure-10 shows the EM simulated insertion loss and return loss of the proposed curve SIW resonator bandstop filter and Figure-11 to Figure-13 shows result for rectangular SIW resonator bandstop filter.

It is observed that the stop band frequency for single (Figure-8), cascaded (Figure-9), and coupled cascaded curved (Figure-10) SIW resonator proposed bandstop filter are at 9.028 GHz, 9.125 GHz, and 8.72 GHz with -3 dB bandwidth of 60 MHz, 70 MHz, and 90 MHz respectively. Attenuation levels at stopband are -24.9 dB, -42.2 dB, and -61.9 dB respectively.

The stopband frequency of coupled cascaded curved and rectangular SIW resonator bandstop filter was shifted slightly to lower frequency after coupling between resonators is introduced. In the upper passband of the coupled cascaded curved SIW resonator bandstop filter response (Figure-10), a harmonic was occur at 9.06 GHz with -12 dB attenuation.

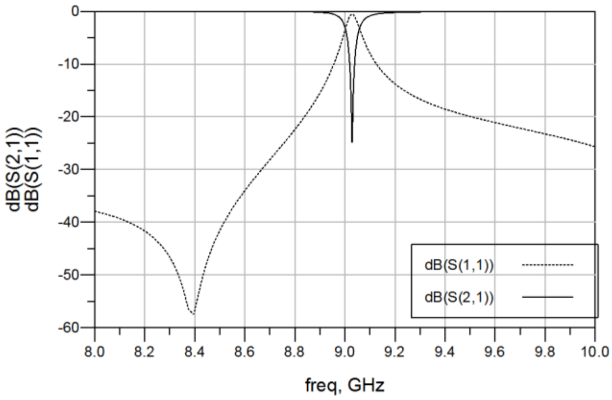

Figure 8: Single curved SIW resonator bandstop filter simulated result

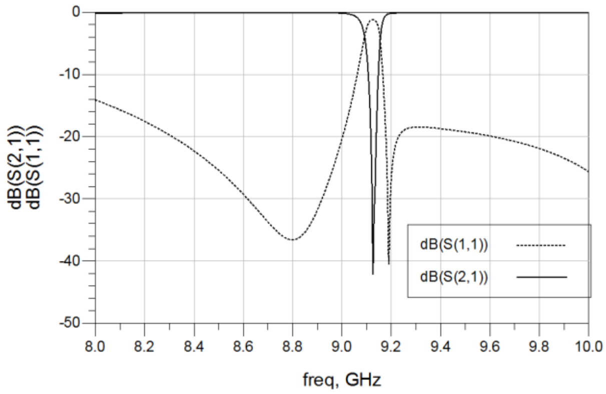

Figure 9: Cascaded curved SIW resonator bandstop filter simulated result

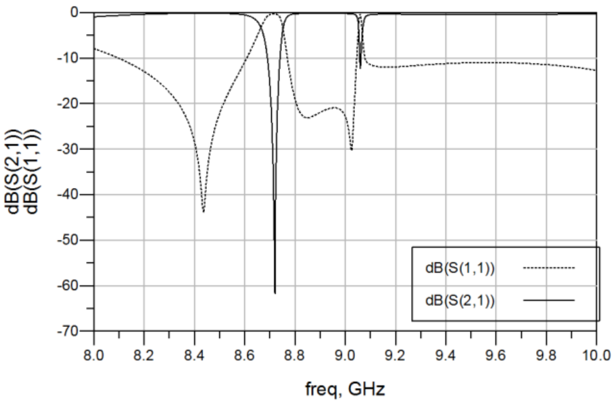

Figure 10: Coupled cascaded curved SIW resonator bandstop filter simulated result.

The stop band frequency for single (Figure-11), cascaded (Figure-12), and coupled cascaded rectangular (Figure-13) SIW resonator proposed bandstop filter are at 9.001 GHz, 9.01 GHz, and 8.796 GHz with -3 dB bandwidth of 40 MHz, 70 MHz, and 120 MHz respectively. Attenuation levels at stopband are -20.6 dB, -37.6 dB, and -63.8 dB respectively.

In the upper passband of the coupled cascaded rectangular SIW resonator bandstop filter response (Figure-13), the return loss (S1,1) was decrease in performance after 9.3 GHz after coupling between resonator is introduced.

Curved SIW resonator bandstop filter was designed to reduce overall length of the rectangular shape SIW resonator filter. The length of coupled cascaded rectangular SIW resonator filter (Figure-7) is 62 mm, while for coupled cascaded curved SIW resonator filter (Figure-4) is 42.6 mm. The overall height of coupled cascaded rectangular and curved SIW resonator filter is 18 mm and 26.5 mm respectively.

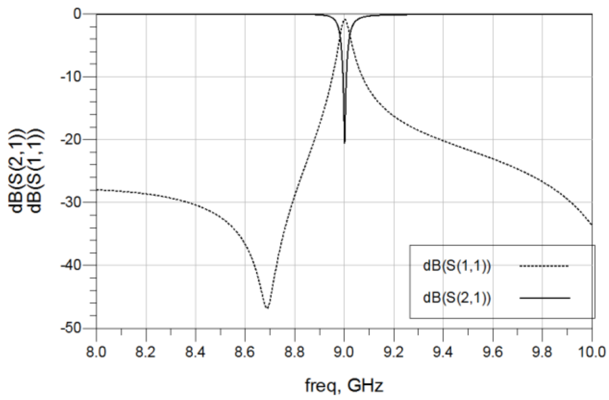

Figure 11: Single rectangular SIW resonator bandstop filter simulated result

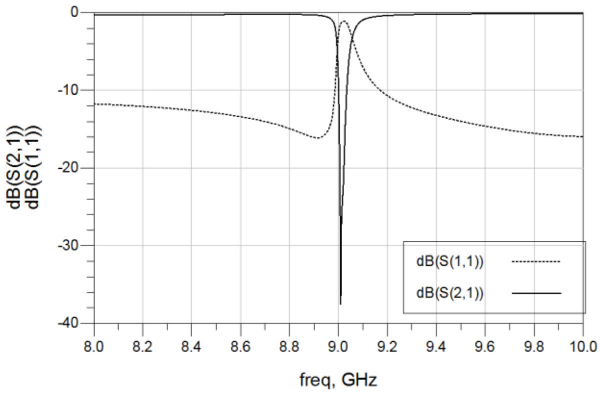

Figure 12: Cascaded rectangular SIW resonator bandstop filter simulated result

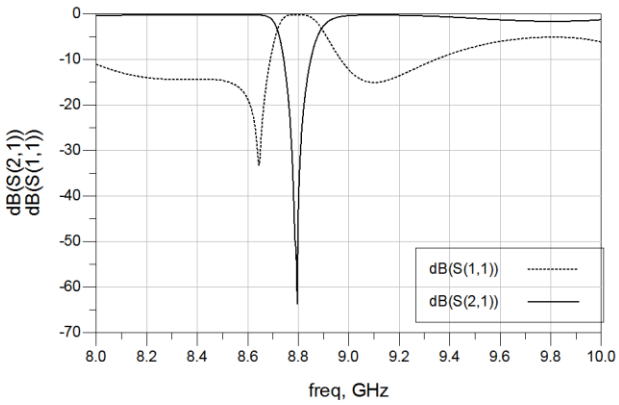

Figure 13: Coupled cascaded rectangular SIW resonator bandstop filter simulated result

B. Comparison of Bandstop Filter Using Different Siw Resonator

From the simulated result of single, cascaded, and coupled cascaded curved and rectangular SIW resonator bandstop filter, all result were compared to other SIW resonator bandstop filter configuration presented in [7,8] on X-band, almost near to 9 GHz. Table-1 show the comparison of frequency response for different type of SIW resonator bandstop filter.

A design by B. H. Ahmad et. al. [7] two stage rectangular SIW bandstop filter with step impedance on the microstrip line coupled to the resonator shown in Figure-14. It used four SIW resonator. A resonator was cascaded and then cascaded to improve the performance compared to single SIW resonator.

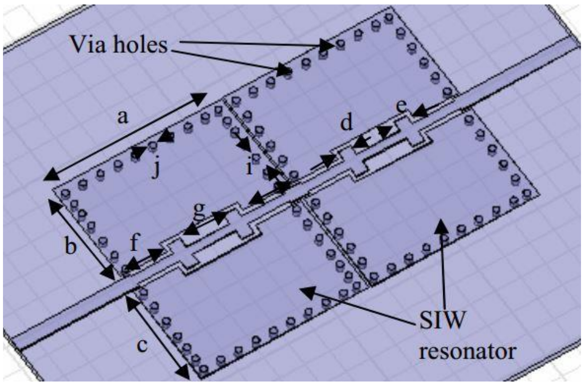

Figure 14: Two stage SIW bandstop filter with arrays of via holes. Dimensions are a = 12.3 mm, b = 8.2 mm, c = 8.2 mm, d = e = 1.0 mm, f = g = h =3.4 mm, i = 1.4 mm, j = 0.5 mm [7]

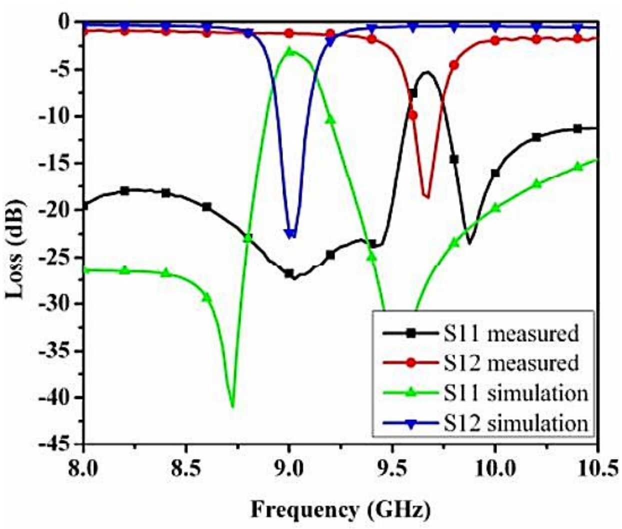

Figure 15: Simulated and measured result for two stage SIW bandstop filter [7]

Another three design of SIW bandstop filter was introduced in [8] by M. N. Husain et. al.; Rectangular, circular, and radial cavity SIW resonator. The width of the cavity resonator for the input signal for the three designs are to 8.3mm.

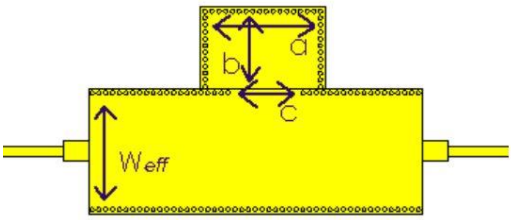

Figure 16: Configuration of rectangular cavity resonator SIW bandstop filter. Dimensions are a = 13.06 mm, b = 9 mm, c = 8.3 mm [8]

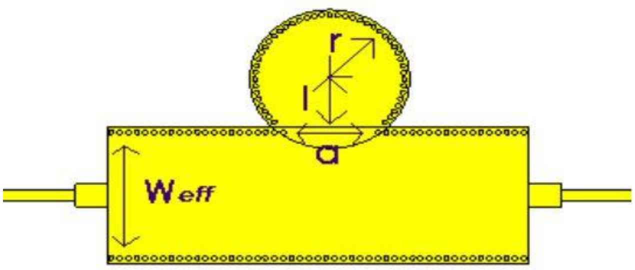

Figure 17: Configuration of Circular cavity resonator SIW bandstop filter. Dimensions are a = 8.3 mm, r = 6.2 mm, l = 4 mm [8]

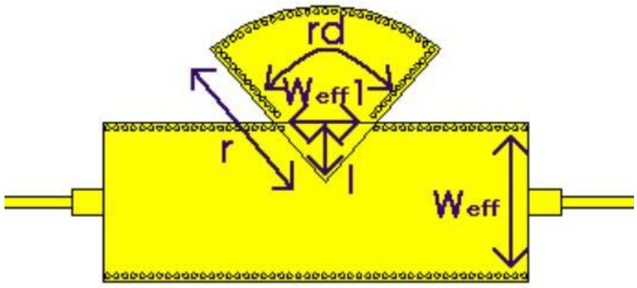

Figure 18: Configuration of dimensions in a radial cavity resonator SIW bandstop filter. Dimensions are rd = 90°, r = 15.5 mm, Weff1 = 8.3 mm, l = 6 mm [8]

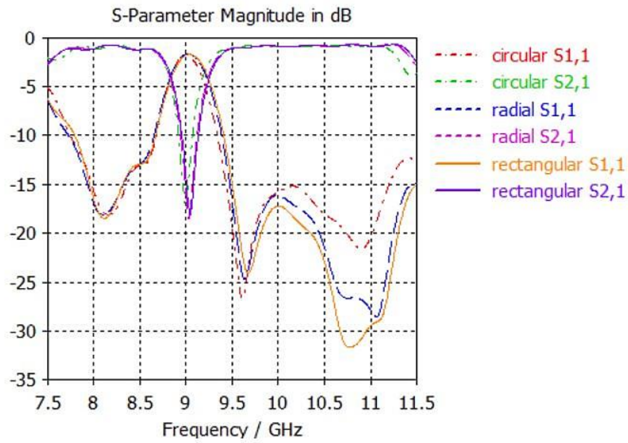

Figure 19: Measured result for rectangular, circular, and radial SIW cavity resonator [8]

Table 1
Frequency response of different types of SIW resonator

SIW resonator	$f_{Stopband}$ (GHz)	Bandwidth (MHz)	Attenuation (dB)
Single Curved	9.028	60	-24.9
Cascaded Curved	9.125	70	-42.2
Coupled Cascaded Curved	8.72	90	-61.9
Single Rectangular	9.00	40	-20.6
Cascaded Rectangular	9.01	70	-37.6
Coupled Cascaded Rectangular	8.796	120	-63.8
Two stage [7]	9.00	400	-23
Rectangular [8]	9.04	498	-18.1
Circular [8]	9.00	450	-17
Radial [8]	9.03	492	-18.6

IV. CONCLUSION

After simulation done in EM simulation using Advanced Design System Momentum RF software, the proposed bandstop filter has shown excellent frequency response performances including high Q and high attenuation property within designed bandstop range. Coupled cascaded curved and rectangular SIW resonator bandstop filter was slightly shifted to lower frequency and poor frequency response at the upper passband region.

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