Novel Compact Wide-band Substrate Integrated Waveguide Bandpass Filter using Conductor Backed Coplanar Waveguide as Feed line for W-Band Communication Applications

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ABSTRACT
In this paper a novel compact Substrate Integrated Waveguide (SIW) filter is proposed. A wideband band pass filter for microwave and millimeter-wave systems is investigated at 80 GHz center frequency with 10.5% fractional bandwidth. A Conductor backed coplanar waveguide is inserted in Substrate Integrated Waveguide (SIW) structure as transition to achieve sharper skirt characteristics. Simulated results show good passband characteristics over a frequency range 75.9 GHz to 84.3 GHz depicting 0.1 dB insertion loss and minimum of 56 dB return loss.

Keywords
Millimeter-wave, Substrate Integrated Waveguide (SIW), Bandpass filter, Coplanar waveguide, W-Band.

1. INTRODUCTION
Metallic wave guide are used for transmitting electromagnetic energy. But they are bulky and expensive to manufacture. These waveguides also exhibit various losses such as copper loss, dielectric loss and radiation loss [1][2]. An alternative option to metallic waveguides is synthesized called substrate integrated waveguides (SIW). SIW is designed with linear array of metallic cylindrical holes known as posts are implanted inside the same substrate along the side walls of substrate. SIW filter shows many advantages over microstrip line filters and metallic waveguide filter such as low loss, high qualify factor, compact size, light weight and easy to integrate and fabricate with other planar and non-planar circuits. After the development of laminated waveguide various efforts have been made to the progress of SIW technology [3]. SIW technology found applications in various microwave and millimeter wave circuits components including various passive and active SIW components such as millimeter-wave resonators [4],oscillators[5], power dividers [6], phase shifters [7], antennas [8], circulators [9],diplexers [10] and directional couplers [11]. Filters are backbone of microwave and millimeter-wave communication systems. A lot of work has been done by many researchers in designing SIW filters. SIW is a high pass filter as it inherits high pass characteristics of conventional waveguide and bandpass characteristics of periodic structures [12]. Various wideband bandpass filters are realized with different geometrical parameters [13]. To improve the response SIW filters with defected grounds [14], complementary split ring resonators [15] and multi-layered substrate integrated waveguide elliptic filters [16][17] have been designed. To minimize the size of filters double folded SIW resonators developed using LTCC (low temperature co-fired technology) [18]. To improve quality factor half mode substrate integrated waveguide (HMSIW) is synthesized on planar substrate [19]. Planar bandpass filters using hybrid structure of SIW and coplanar waveguides are designed [20]. Filters in ultra wide band range are also designed. In this paper a compact SIW wideband bandpass filter from 75.9 GHz to 84.3 GHz frequency range with fractional bandwidth of 10.5% is investigated. The filter exhibit good pass band characteristics with 0.1 dB insertion loss and minimum 56 dB return loss, which is suitable for use in various microwave and millimeter-wave circuits.

2. DESIGN ANALYSIS
SIW structure is a progression between microstrip and dielectric filled waveguide (DFW). SIW is a linear periodic arrangement of metallic vias or holes which are embedded along the side walls of waveguide. SIW structure supports the propagation of quasi transverse electric (TE) modes. Microstrip lines and coplanar waveguides (CPWs) are integrated to SIW as feed lines. These are transition system to connect easily with other circuits. When boundary conditions are applied to a section of SIW, a cavity resonator is obtained. The resonant frequency is given by Changjun Liu [21]:

$$f_{mon} = \frac{c}{2\sqrt{E_{eff}}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2} \qquad (1)$$

Where m, n represents the mode number, E_{eff} is the effective permittivity, a and b are longer and wider dimensions, c is the speed of light in free space respectively.

Various electromagnetic field distributions along with their modes determine the resonant frequencies. In this paper we inserted the metalized holes in the structure as shown in figure 1 are arranged in such a way that it produces wideband bandpass filter with minimum attenuation by adjusting various parameters such as p (pitch length), d (via diameter), W_c (distance between two metallic arrays).

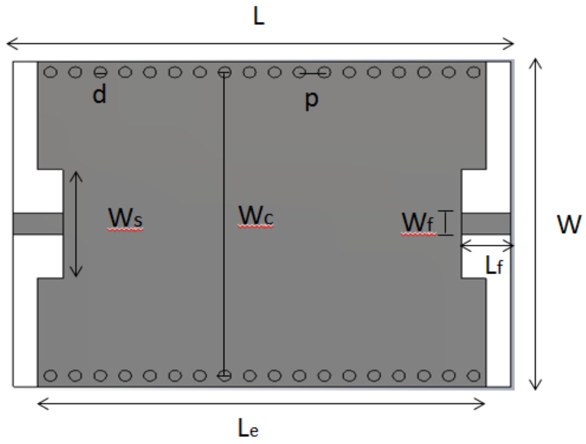

Figure 1: Substrate Integrated Waveguide Bandpass Filter Structure

The inserted metallic holes reduces the size of structure in comparison with [21]. Major role of improving the pass band performance of structure is to use a conductor backed coplanar waveguide, which is used to connect SIW by cutting the slots on input and output sides of structure. By increasing the length of slot electric coupling and magnetic coupling is improved which in turn improves the filter performance.

3. SIW BANDPASS FILTER DESIGN PARAMETERS

The SIW wide band pass filter with the metallic holes inserted inside the SIW with a geometrical systematic arrangement is shown in figure 1. It gives more fractional bandwidth and compact size in comparison with [21] with improved return loss less than 56 dB. The SIW band pass filter is designed at 80 GHz center frequency. Finally we introduce the following empirical design formulae of the proposed SIW band pass filter whose fractional bandwidth is about 10.5 %.

$$W = \frac{2.14c}{f_c\sqrt{\epsilon_r}} \quad (2)$$

$$L_e = 1.2 * W \pm d \quad (3)$$

Where c is the speed of light, ϵ_r is relative permittivity of material and f_c is center frequency.To minimize the radiation loss and return loss following conditions must be satisfied:

$$d/p \geq 0.5 \quad (4)$$

$$d/W_c < 0.4 \quad (5)$$

Where d is diameter of vias, p is called pitch length or spacing between two vias, W_c is distance between two metallic arrays. Metallic holes are inserted along the side walls of structure with parmeters d, p and W_c satisfying above equations which help in reducing the size of filter and wider passband is achieved as shown in Figure 2. Conductor backed coplanar waveguide is inserted in SIW as transition to obtain sharper skirt. The SIW structure is designed by using a substrate with relative permittivity, ϵ_r of 2.2 and height of 0.762 mm. The following table 1 gives the parametric values of filter design with matched port configuration at 50Ω.

Table 1: Substrate Integrated Waveguide (SIW) Bandpass filter Parameters. Unit: mm

Le	7.2mm
L	8mm
Wc	5.6mm
W	6mm
Wf	0.4mm
Ws	2mm
P	0.4mm
D	0.2mm
Lf	0.8mm

Where L_e is the length of SIW, L is structure length, W_c is distance between two metallic arrays, W is width of SIW, W_f is feed line width also known as coplanar waveguide and W_s is slot width, p is pitch length, d is diameter of vias and L_f is length of feed line.

4. SIMULATED RESULT

We use CST microwave studio suite to carryout simulations and optimize the filter size**.** Full wave simulation response is shown in figure 2. S_{11} parametric curve shows the return loss and S_{21} parametric curve shows insertion loss. The 3-Pole filtering characteristics represents the 3dB bandwidth of 8.4 GHz with fractional bandwidth of 10.5 % depicting minimum insertion loss 0.1 dB and return loss less than 56 dB.

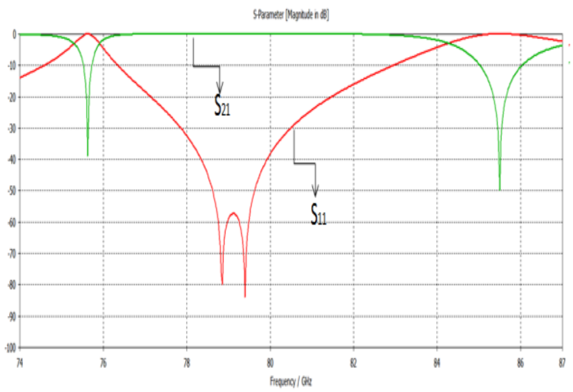

Figure 2: Simulated result of 3- Pole Substrate Integrated waveguide Bandpass filter depicting Insertion loss (S21) and return loss (S11)

5. CONCLUSION

This research paper presents a novel compact SIW band pass filter design criterion. The proposed filter design is simulated on CST microwave studio software. The simulated results show good pass band performance with 0.1dB insertion loss and minimum 56 dB return loss at 80 GHz center frequency. The fractional bandwidth obtained is 10.5%. The filtering characteristics are improved using conductor backed coplanar waveguide. The proposed band pass filter is of compact size and wide bandwidth. The filter is suitable for various applications in W- band communication.

6. ACKNOWLEDGEMENT

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