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Design of Substrate Integrated Waveguide Bandpass Filter for X Band Applications

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ABSTRACT
This paper presents the design of substrate Integrated waveguide (SIW) bandpass filter for the X band (8 GHz to 12 GHz) applications. Substrate integrated waveguide is quite popular in filter design due to its high performance.The bandpass filter is used to receive the desired band of frequency and to reject the frequency which is out of interest. In this paper, we used the U slotted structure to improve the stopband performance of the filter at the upper band of frequencies. Taper section is provided to avoid the sharp transition from the feedline to the SIW structure which improves the S_{11} performance of the filter. The simulated results are obtained from the CST software. The results show that the designed filter gives better performance and it is well suitable for the X band applications.

Keywords- Isolation, Insertion, SIW, Tapered region, U slots, Filter

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I. INTRODUCTION

The microwave filters are used to receive the desired band of frequencies and to reject the all other frequencies which are out of the interested region. These filters are widely used is the different field of communication like wireless communication and satellite communication. It can be used in RF broadband systems. Low insertion loss, small size and low cost and high selectivity are some of the essential design parameters that designer should think about, but the old technology is not capable of providing all these characteristics at the same time. Substrate integrated waveguide is new technology which can be used to design the microwave and millimetre wave component's like a filter, antennas, couplers etc. substrate integrated waveguide is quite popular due to its low cost, planar structure, high Q factor, high performance etc. [5]. X band is the frequency region of the microwave radio region in the electromagnetic spectrum which occupies the frequencies from 8 GHz to 12 GHz. X band is mostly used in the Radar applications including continuous wave, pulse, single polarization, double polarization etc. different types of filters have been purposed for X band application, but they are difficult to fabricate due to their complex structures. In this work, we designed the SIW bandpass filter for X band (8 GHz to 12 GHz) applications using U slotted structure and taper section which improves the performance of the filter.

II. SIW FILTER DESIGN PROCEDURE

The SIW structure consists of the top and bottom metallic planes of a substrate, and also it consists of the parallel arrays of via holes at both the sidewalls. The length of the SIW filter can be calculated by using Eq. 1 given below.

$$f_{cutoff}=\frac{c}{2\Pi\sqrt{\varepsilon r}}\left(\sqrt{\left(\frac{m\Pi}{l}\right)^2}+\sqrt{\left(\frac{n\Pi}{w}\right)^2}\right) \quad (1)$$

For the dominant mode (TE_{10}), the above equation can be given as

$$f_{cutoff}=\frac{c}{2l\sqrt{\varepsilon_r}} \quad (2)$$

Where

'f_{cutoff}' is the lower cutoff frequency of the filter and 'l' as shown in figure 1 can be calculated by using the Eq. 2. 'c' is the velocity of the light in the free space and 'ε_r is the dielectric constant of the substrate. The values of p and d can be calculated by using Eq. 3 and Eq. 4 respectively.

$$d<\frac{\lambda_g}{5} \quad (3)$$

$$p=2*d \quad (4)$$

Where
'λ_g' is a guided wavelength which is calculated by using Eq.5 as follows

$$\lambda_g=\frac{\lambda_{ms}}{\sqrt{\varepsilon_{reff}}} \quad (5)$$

Where,
'λ_{ms}' is microstrip patch wavelength for the center frequency 'f_c'.

To avoid the sharp transition from feedline to the SIW structure we have to provide the tapered section which improves the S_{11} performance of the filter [7]. The length and width of the taper can be calculated using the following equations.

$$L_{tap} = 0.2368 * \lambda_g \ (6)$$

$$W_{tap} = W_f + 0.1547 * l_{eff} (7)$$

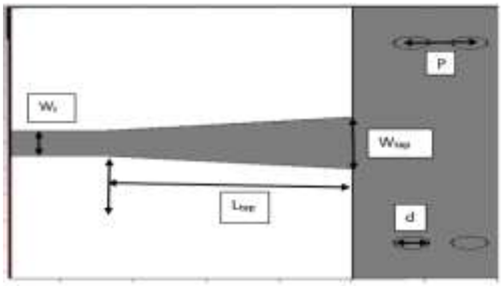

Fig 1: Structural parameters of the microstrip taper transition between a microstrip line and SIW

Where W_f is about the one eight of the length of the parallel array of vias. 'L_{tap}' and 'W_{tap}' are length and width of the taper region respectively [7].

U slotted structure is to improve the stopband performance of the filter at the upper frequencies and also to get the better resonance. The size of the U slot can be determined by the equation given in [2] [8].

By using the value of 'l', the remaining values of the filter can be calculated.W is a width of the SIW, L is a length of SIW, $W_{eff}$is an effective width of SIW, L_{eff} is the effective length of the SIW, d is the diameter of the via, and p is the pitch of the via array.

Using all the above mention design equations, one can calculate the design parameters of the SIW structure.

Using above equations and some optimization the designed parameters values for the SIW filter are calculated. To get the desired results, the optimization is done on the computed values. The designed parameters after optimization are given in table 1.

Parameters	**Value (mm)**
L	14
W	9
L_{eff}	11.6
W_{eff}	24.8
d	1.4
p	2
W_{tap}	3.4
W_f	1.2
L_{tap}	5.2
w_s	1.4
l	10.9
l_s	3.6

Table 1: Designed parameters and corresponding values

III. DESIGNED FILTER

The fig. 2 shows the geometric structure of the designed bandpass filter for the X band applications. All the dimensions of the filter designed are calculated by designequations mention above, and optimization is done on the calculated values to get the proper results in the desired band.

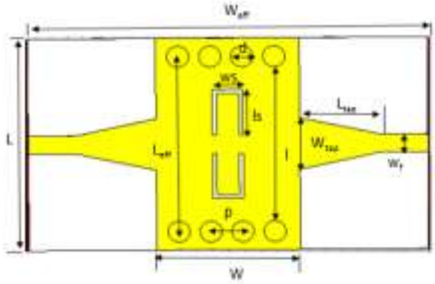

Fig 2: SIW Bandpass Filter

Substrate specification

The above filter is designed in CST (Computer Simulation Technology). The substrate specification for the designed filter is given in table 2.

Material	RT6002 (lossy)
Type	Normal
Dielectric constant	2.94
Substrate thickness	0.5 mm

Table 2: Substrate Specifications

IV. SIMULATION RESULTS

The simulation plots for the design are shown in the fig. 3. The figure consists of both the plots i.e.S_{11} and S_{21} plots. The result and performance parameter of the filter will be discussed in this section.

From the plot we can see that the filter gives the better S_{11} value of -43 dB at the frequency of 10.57 GHz also the S_{11} plot occupies the X band (8.3 GHz to 11.9 GHz). Insertion loss plot shows that the S_{21} plot remains below 0.8 dB in the region of interest. It gives better stopband performance at upper frequencies due to U slotted structure.

The simulated results for the purposed design are summarized in table 3.

Frequency band	8.3 GHz to 11.9 GHz
Insertion loss	Less than 0.8 dB
Return loss	-43 dB at 10.57 GHz

Table 3: Simulation Results

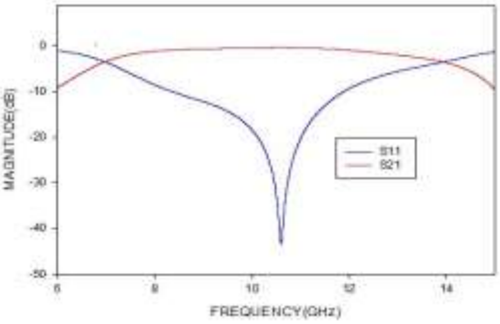

Fig 3: S_{11} and S_{21} plots for the purposed filter

V. CONCLUSION

The conventional filter for X band are very complex and hence difficult to fabricate. In this work, we designed the bandpass filter using substrate integrated waveguide technology which provides ease of fabrication as it is compact and also the use of U slotted structure help to improve the stopband performance at upper frequencies. The Sharp transition from feedline to SIW structure affects the S_{11} performance of the filter. We added taper section to avoid the sharp transition from feedline to SIW structure which improves the S_{11} performance of the filter. The filter possesses low reflection, good isolation, low cost and also the size of the filter is less hence it is compact. The above all mention advantages makes the purposed filter well suitable for the X band applications.

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