Design of Millimeter Wave Substrate Integrated Waveguide Band Pass Filter

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Abstract— This paper presents a substrate integrated waveguide (SIW) and SIW band pass filter. The proposed filter is designed by making the cavities in the SIW. Initially, a substrate integrated waveguide is designed and simulated and the propagation constant is investigated. Then a substrate integrated waveguide cavity band pass filter is proposed and simulated. The various parameters of the filters, such as reflection and transmission loss, are also analyzed. The proposed filters show the band pass filter characteristics in the K frequency band applications that are useful for future millimeter wave applications.

Index Terms— SIW, filter, millimeter wave

1 INTRODUCTION

The substrate integrated waveguide (SIW), a useful and exciting planar technique, has the potential to generate a lot of interest in the design of microwave and millimeter-wave integrated circuits. The fabrication of the SIW, a periodic structure with a linear array of metallic vias, takes place on a dielectric substrate. Because the field distribution in a SIW is identical to that of a typical rectangular waveguide, it inherits the benefits of the rectangular waveguide, such as high factor, low insertion loss, and high power capacity. In low-temperature co-fired ceramics, this approach can also be used to create ridged waveguides. Laminated waveguide and post-wall waveguide are two alternative terminologies for similar LTCC structures. Filters, multiplexers, antennas, and power dividers are examples of components.[1-4]

The SIW technology enables the integration of active devices, passive structures, and other components into a single substrate, implying that full wireless systems can be incorporated into the SIW technology [5-8].Because it's far tough or maybe physically and electrically not possible to fulfill all layout standards or specs on the identical time, the clothier can be compelled to make a compromise among several conflicting requirements. For example, accomplishing better channel selectivity generally necessitates using extra resonators within side the first order that allows you to bring about a better insertion loss alongside the transmission direction due to the fact the insertion loss is kind of proportional to the range of resonators used within side the clear out construction [9, 10]. For low insertion loss and hence low noise figure, a band pass filter comprised of resonating elements such as cavities requires a large number of high unloaded quality factor resonators. At microwave frequencies, a resonator's unloaded quality factor is often proportional to its volume and cost. [11-12].

This is linked to the mode of resonance (field profiles within the structure) and material quality, in filter design and construction, there is always a balance between performance needs and development costs [13-17]

This paper shows the design of SIW and SIW band pass filter based on cavity resonators. The propagation constant of the designed SIW is also evaluated along with the scattering parameters of the SIW filters. The main advantages of the proposed filter are the very low insertion loss in the pass band and the high value of selectivity.

2 DESIGN OF SIW AND SIW FILTER

Detailed The SIW is designed on a dielectric material of dielectric RT duroid 5880 of relative dielectric constant of relative dielectric constant of 2.2 a, substrate height of 0.762. . For the dominant TE_{10} mode, the cutoff frequency for the rectangular waveguide is calculated from the given formula.
Submission

$$f_c = \frac{c}{2a} \tag{1}$$

Where c is the velocity of light and a is the width of the rectangular waveguide.

For the dielectric filled waveguide the same cut off frequency, the width is

$$a_d = \frac{a}{\sqrt{\varepsilon_r}} \tag{2}$$

Where a_d is the width of the rectangular waveguide and ε_r is the relative dielectric constant of the dielectric material.

The width of the equivalent SIW is calculated from the following formula

[6].

$$a_{s=} a_d + \frac{d^2}{0.95p} \tag{3}$$

Where a_s the width of the SIW, p is the spacing between the vias and d is the diameter of the vias. In this work SIW is designed for the cut off frequency of 10.5 GHz. For d=1mm and p=1.5 mm , the calculated width is 8 mm. The length of the designed SIW is 30 mm .The designed SIW is shown in Fig.1

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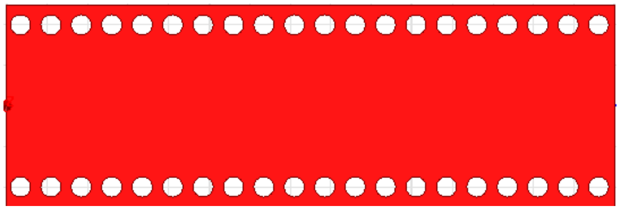

Fig. 1 Designed SIW

The propagation constant of the designed SIW is derived from the HFSS electromagnetic simulator, and the cut-off frequency is also verified from the simulator. The 50 Ohm wave feed technique is used in the simulation. Fig. 2 shows the imaginary propagation constant (phase constant) of the designed SIW.

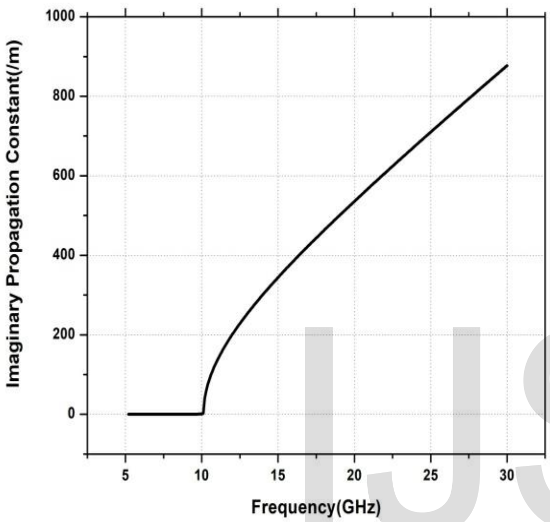

Fig. 2 Imaginary Propagation Constant vs Frequency Curve

It is found that for the dominant mode TE_{10}, the calculated cut off frequency matched the simulating cut off frequency of the proposed SIW and it is clear from the above curve that the designed SIW passes the frequencies above 10.5 GHz with minimal attenuation.

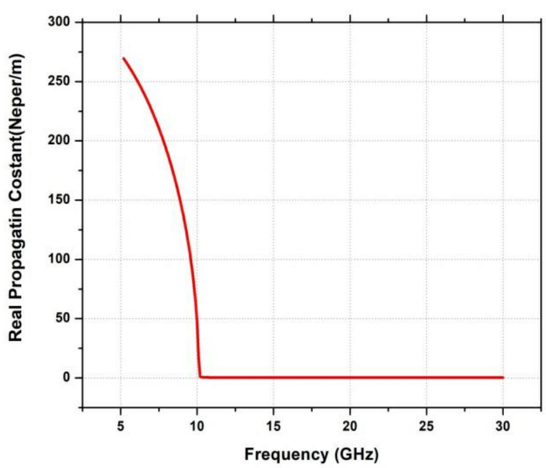

Fig. 3 Real Propagation Constant vs Frequency Curve

The above figure shows that up to the 10.5 GHz filter, the SIW attenuation constant is very high and above this the attenuation constant is almost zero, so the designed SIW acts like a high pass filter. Now the designed SIW is converted into a band pass SIW filter by inserting the probe and making the cavities inside the proposed SIW. The horizontal spacing between each of the vias is $\frac{\lambda_g}{4}$ and the vertical spacing between two $\frac{\lambda_g}{4}$ to $\frac{\lambda_g}{2}$. Where λ_g is the guided wavelength inside the SIW. The characteristics of the structure are change from high pass to band pass. Fig. 4. Shows the designed SIW band pass filter.

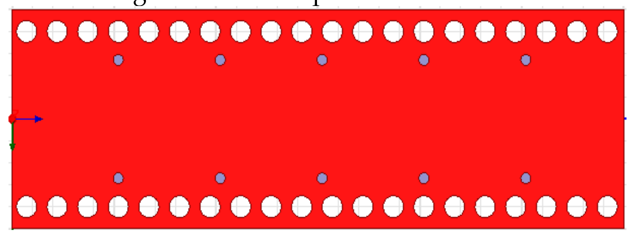

Fig. 4 Designed SIW filter

The return loss and the insertion loss of the proposed SIW filter are derived from the simulator. Figure 5. Shows the return loss (S_{11}) and insertion loss (S_{12}) vs frequency curve of the proposed SIW filter. It is clear from the following curve that the designed SIW filter works like a band pass filter from the frequency of 18 GHz to 22 GHz, in the K band of the electromagnetic spectrum.

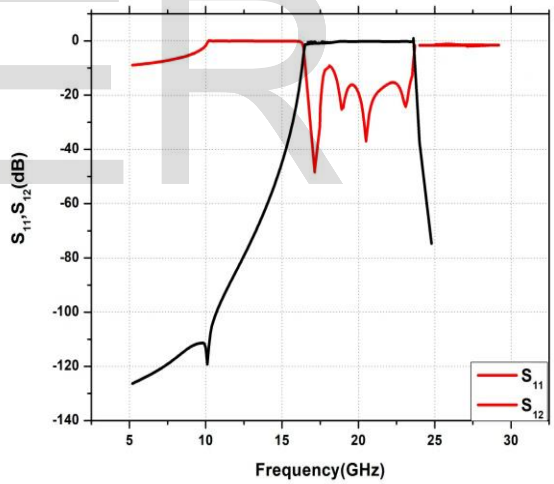

Fig. 5 S11, S12 vs frequency Curve of the designed SIW filter

The proposed filter's minimum return loss is 50 dB, while its insertion loss is less than 0.5 dB. Consequently, the proposed SIW filter exhibits good filter properties in the K band. In order to demonstrate the proposed filter's effectiveness, Table 1 compares it to a number of other SIW band pass filters already published in the references.

Table 1. comparison between the proposed filter and earlier filters from the references.

Reference	Frequency Band	Center Frequency	Return Loss(dB)	Insertion Loss (dB)	Fractional Band width
[4]	Ku	15.6	>19	1	2.68

[8]	K	20.5	>20	1.2	5.2
[14]	Ku	12.5	>15	1.3	9
[15]	Ku and K	18.3	>15	1.35	10.9
This work	**K**	**20**	**>40**	**0.5**	**36.8**

3 CONCLUSIONS

This paper presents two structures: one is the SIW and the other is the SIW band pass filters. The propagation constant of the SIW is investigated, and the insertion loss and return loss of the designed SIW band pass filter are investigated. These two parameters of the SIW filter are good as compared to those presented in other studies. The designed filter is suitable for the K band spectrum that is useful for the future 5 G, IOT sensors, and other millimeter wave applications.

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