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Design and simulation of C-band Substrate integrated waveguide filters for wireless applications

Ms. Janki Vyas **Professor M.A. Jajal**

1 Department of Electronics / Shantilal Shah Engineering College, Bhavnagar, Gujarat, India vyasjanki007@gmail.com ,

2 Department of Electronics / Shantilal Shah Engineering College, Bhavnagar, Gujarat, India majajal@ec.ssgec.ac.in

Abstract

In modern wireless communications, substrate-integrated waveguide filters are used in high-frequency applications. This article provides a review of substrate-integrated waveguide-based microwave filters. Substrate integrated waveguide filter technology is implemented in the uplink and downlink frequency bands of satellite communications. You can use the substrate-integrated waveguide filter design to improve various parameters of existing board-integrated waveguide filters such as size, reflection attenuation (S11), and insertion loss (S21).

Keywords: wireless application, bandpass filter, substrate integrated waveguide

I. INTRODUCTION

In modern wireless communications, integrated waveguide filters are used in high frequency applications and in satellites. The SIW filter design is based on a planar dielectric substrate with both rows of metal layers above and below and metal vias on its sides, separated by a distance proportional to the guide wavelength between them. SIW filters offer compact size, low insertion loss, high Q factor, low cost, high reflection attenuation and light weight.

Filters play an important role in many microwave and radio frequency (RF) applications. Waveguide-based microwave filters are primarily used in satellite applications. These filters that allow a certain range of frequencies to pass and different frequencies are rejected. Traditional waveguide filters have excellent performance, but they are bulky and very difficult to integrate with other components. Currently, SIW filters are used for satellite communications. The advantages of SIW filters are their small size, low insertion loss and low cost.

Manufacture of high frequency waveguide devices is very difficult. That's why a new concept, SIW, has emerged. Therefore, hollow waveguide pipes such as rectangular waveguides. The inside of a rectangular waveguide is usually air. The cross-sectional area can be reduced by filling with a dielectric. Hollow tubes are usually bulky, but Recently, the transition between microstrip structures and waveguides is called a substrate integrated waveguide (SIW) filter. The SIW structure, built on a dielectric material with an upper layer and a lower layer, is a conductor, with two linear arrays of metal vias forming the sidewalls, as shown in Figure 1. Manufacturing process if SIW has the characteristics of being cost effective, integrate able with planar devices, and relatively simple.

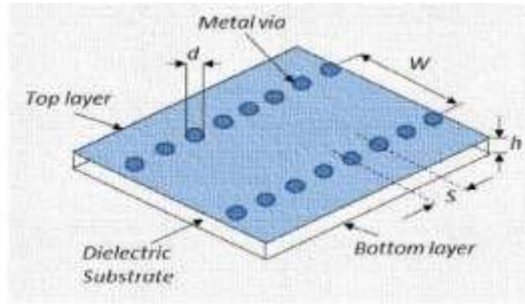

Figure 1: Substrate integrated waveguide (SIW)

Vias are metal cylinders. PCB vias provide a conductive route for passing electrical signals from one layer to the next. Through vias: -Hole from top to bottom. Blind Vias: Blind vias are drilled from the upper or lower layers, but stop at Some points of PCB circuit design. Buried vias: -Used to connect only the inner layer structure. The first 8-layer structure drilled as a through hole from layer2-layer7 of a PCB circuit.

Table: 1 Difference between waveguide and substrate integrated waveguide

Parameters	Waveguide	Substrate integrated waveguide
Integration with another component	Very difficult to integrate When another component	Simple to Integrate with another component
Structure size	Big size	Small size
Structure weight	Bulky weight	lightweight
Production cost	High cost	Low price
advantage	good power processing power	Higher power processing capacity and more compact size
Disadvantage	Bulky size and high cost	Dielectric loss

II. DESIGN PROCEDURE

SIW is designed using the formula shown below. The cut-off frequency of the rectangular waveguide Given by

$$F_c = \frac{c}{2\pi}\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2} \quad (1)$$

Where "c" is the speed of light and "m" and "n" are the modes, that is, the number of half-cycle fluctuations in the field along the x and y axes, respectively. The "a" and "b" represent the length and width of the rectangle. For dominant mode TE10, the above equation is:

$$F_c = \frac{c}{2a} \quad (2)$$

The length (a) of the dielectric-filled waveguide is given by:

$$a_d = \frac{a}{\varepsilon_r} \quad (3)$$

The guide wavelength in the substrate on which the SIW is designed is given by the following equation.

$$\lambda_g = \frac{2\pi}{\sqrt{\frac{\varepsilon_r(2\pi f)^2}{c^2} - \left(\frac{\pi}{a}\right)^2}} \quad (4)$$

Here, "Ɛr" is the permittivity of the material and "f" is the operating frequency. Therefore, the conditions for selecting the diameter (d) and pitch (p) of the metal via are as follows:

$$p < 2d \quad (5)$$

The separation (as) between the periodic sequences is determined using the following equation.

$$a_s = a_d + \frac{d^2}{0.95p} \quad (6)$$

III.SIW BAND PASS FILTER FOR 5.3 GHZ GPR RADAR SYSTEM

In this study, we proposed a SIW bandpass filter for radar wire less systems. This is a step frequency, with a focus on new C-band GPR Radar System, it's frequency range is 4.8 to 5.8 Ghz , this filter operating in the 5.3 GHz frequency band.

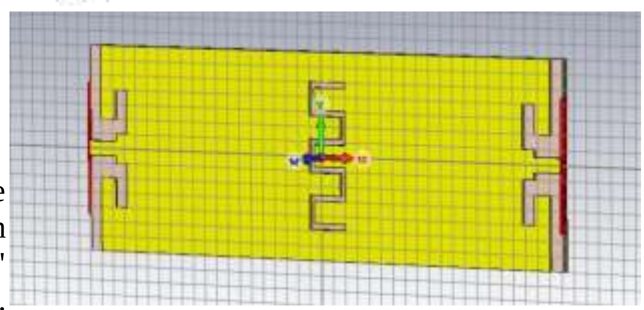

Figure 2. Half inter digital circuit

Here you can use FR-4 (lossy) to calculate the length of the resonator with the board, as shown in Figure 2. The substrate used in the current design is FR-4 (loss) with a dielectric constant (Ɛr) of 4.3 and a height (h) of 0.508 cm.

Several simulations were performed by varying the length and width of the resonator up and down until the best insertion loss and reflection attenuation values were obtained.

Smaller sizes and shorter distances between the two central resonators result in narrower bandwidth and improved insertion loss values, but the lower and upper frequency limits are not suitable for the target, so the resonator on the filter I returned to adding. It is shown in Figure 2.

Figure 2 shows the proposed filter configuration. It consists of a central half-cascade cell and two SIW transitions at the input / output (I / O) ports or tappers to improve insertion loss and return loss.

In Figure (3), the patch parameter has a metal hole. These vias are shown in Table II.

Table: II

SR.NP.	frequency (GHz)	diameter (CM)	pitch (CM)
1.1.	5 GHz	0.5	2.5

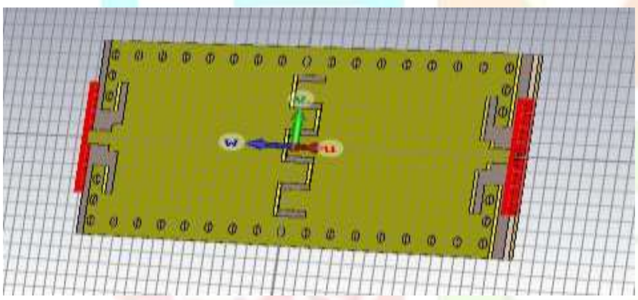

Figure 3. SIW bandpass filter design

Figure (4) shows the three stages of the filter.

Substrate, patches. The design of the upper and lower layers is copper (annealed), and the thickness is 0.2 mm.

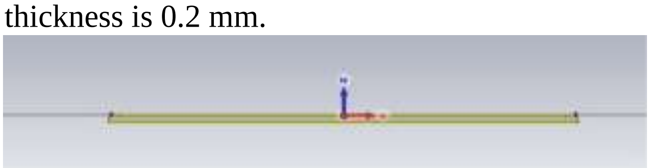

Figure 4 Bottom view of the filter

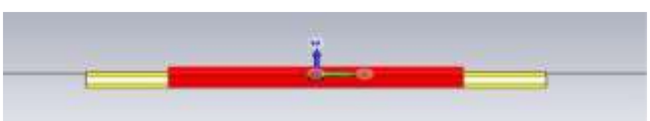

Figure 5. Side view of waveguide

IV. SIMULATION

Table III shows a study of the parameters for optimizing the dimensions of the bandpass filter. We changed the cell size and distance for accurate returns and insertion loss, as well as the parameter of certain waveguides.

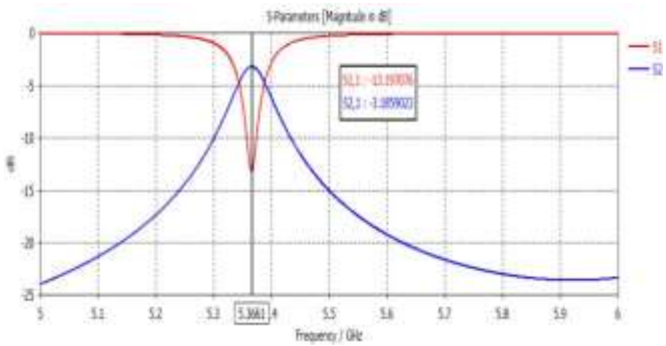

Figure 6. Simulated reflection loss and insertion loss

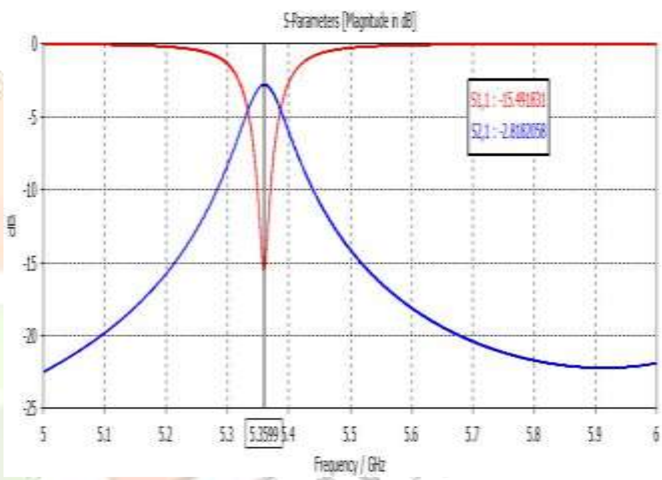

Figure 7. Simulated reflection loss and insertion loss

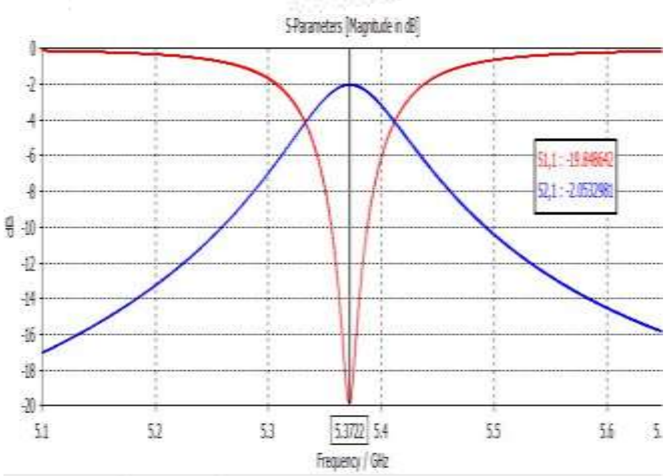

Figure 8. Simulated reflection loss and insertion loss

Table: III

Figure	Figure 1	Figure 2	Figure 3
Return loss (S11)	-13.19	-15.49	-19.84
Insert Loss (S21)	-3.18	-2.81	-2.05
Cut-off frequency	5.36	5.35	5.37

The simulation shows good performance with a 5.3Ghz bandpass filter. At the last frequency, the return (S11) is 19.84dB and the insertion loss (S21) is -2.05dB. The bandwidth of this filter is 50Mhz and the Q factor is 107.44.

V. CONCLUSION

In this paper, SIW-based bandpass filters with metal vias operating over a radar range of 5.3 GHz are designed for very low insertion loss and reflection attenuation. The bandpass characteristics of the filter are analysed and the desired radar frequency is extracted from the simulation results. GHz bandpass using CST STUDIO. The same can be manufactured on a cost-effective substrate with low loss to evaluate actual properties. The discrepancy is mainly due to many parameters such as the dimensions of the filter manufactured, the thickness and dielectric constant of the substrate from which the filter was manufactured.

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