Design of an Offset Posts K- band Bandpass Filter using Substrate Integrated Waveguide for Microwave Applications

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Abstract*: In this paper, an offset posts K-band bandpass filter has been designed using substrate integrated waveguide (SIW). SIW is formed inside a dielectric material by applying a top metal over the ground plane and trapping the structure on either side with rows of plated vias. SIW is effective and efficient solution in waveguide technique. The slotted windows are cut in tapered transition of SIW filter to attain low loss. The proposed filters are designed at 23 GHz center frequency. The simulated results exhibit low losses and sharp roll off characteristics in pass band. There is good agreement between the simulated results and the experimental results. The proposed filter is suitable for use in microwave communication devices.

Keywords*: substrate integrated waveguide; microstrip; conventional waveguide; vias; tapered transition; K-band; offset posts; microwave Communication devices.

I. INTRODUCTION

A microwave filter is usually a system which is used for frequency selectivity over the 300 MHz-300GHz frequency range by allowing effective transmission of signals within the filter passband, while excluding signals in the filter stop band [1]. Waveguide is a good option for incorporating low loss filters, high performance and high Q factor [2]. Nevertheless, the development and integration with several other integrated circuits is comparatively expansive and complex. Planar microwave mechanisms, such as the microstrip line and coplanar microstrip section, are easy to fabricate and combine with other electronic systems, but these planar filters are more lossy compared to waveguide filters, mainly at a relatively high frequency [3].

It is therefore important to produce innovative filter configurations that can be effectively produced and integrated with other systems while maintaining low loss, superb stopband performance, high power efficiency and high selectivity to better accommodate the more stringent regulations of modern communication networks. The SIW is a wave-guide system established using metallic via arrangements incorporated in a dielectric substrate that connects two parallel metal plates electrically [4]. This incorporates the advantages of both the conventional waveguide system and the planar circuit, such as low leakage, low cost, fast production and high integration. Previously, the SIW design was presented as a form of embedded laminated waveguide which could be comfortably produced using the standard printed circuit board (PCB) production technique. Later, it was established as a lightweight, scalable, low-loss and price-effective interface for designing and integrating passive components, active circuits and dissipating elements into a dielectric substrate, due to its desirable attributes. Since the invention, SIW technology has grown various microwave and millimeter-wave modules, such as antennas, power dividers, couplers, filters, and diplexers [5]-[7] etc. Microwave filters are amongst the most advantageous technologies investigated in the SIW region. A number of filters have been constructed using SIWs with different configurations [8],[9]. From the surface current view, a significant physical interpretation for the modes that reside in the SIW has been provided in [10]. As is understood, the surface currents are formed when a mode is set in a guided-wave configuration. The SIW can be viewed as a unique rectangular wave guide on the sidewalls with a set of vertical holes. When the slots cut off the current flow direction, i.e. Modes of TEn0 will only produce very little radiation and therefore these modes can be maintained in the waveguide [11]. In this paper, an offset posts K-band bandpass filter using a substrate Integrated waveguide technology is proposed.

II. DESIGN CRITERION OF SIW WAVEGUIDE

A. Effective Width of the SIW

It can be seen that the cutoff frequencies of the TE10 and TE20 modes in the SIW can be interpreted as follows, with reference to the diameter of the metallized vias and their spacing [12]:

$$f_{c\,(TE10)} = \frac{C_0}{2\sqrt{\varepsilon_r}}\left(w - \frac{D^2}{0.95.b}\right)^{-1} \quad (1)$$

$$f_{c\,(TE20)} = \frac{C_0}{\sqrt{\varepsilon_r}}\left(w - \frac{D^2}{1.1.b} - \frac{D^3}{6.6.b^2}\right)^{-1} \quad (2)$$

Where C_0 is the speed of light in free space; w is the width of the SIW, D isthe via diameter and b is the via spacing. This equation is valid for D< $\lambda_0\sqrt{\varepsilon_r}/2$ and b < 4.D.

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The filter dimensions are calculated by considering below design rules. SIW parameters are calculated as [13]:

$$L_{SIW} = L_{eff} + \frac{d^2}{0.95p} \quad (3)$$

$$W_{SIW} = W_{eff} + \frac{d^2}{0.95p} \quad (4)$$

B. Minimisation of the Losses of the SIW

The reduction of losses is one of the key issues in the development of SIW modules. There are specifically three loss processes within SIW. Due to the restricted conductivity of metallic edges and the loss of tangent of dielectric substrate, the SIW has conductive losses as well as dielectric losses such as the traditional waveguide. Furthermore, the occurrence of openings along the SIW side walls can result in a loss of energy due to the potential leakage via these gaps [14].

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

$$b < 2.D \quad (6)$$

where λ_g is the guided wavelength in the SIW.

C. Design of An Offset Posts Bandpass Filter

The forthcoming filter is modeled by installing metallic cylindrical openings inside the substrate in offset geometry Full wave electromagnetic simulation technology performs simulation and parametric assessment of the filter. The performance evaluation and parametric study indicates that inserting metallic holes within the design with appropriate diameter and sufficient gap in offset topology resulted in low loss Bandpass filter. The connected tapered transitions are used to link power from input to output sides. The Bandpass performance of the implemented filter shows an insertion loss of 0.06 dB and a return loss of 30 dB at a center frequency of 22.9 GHz. The anticipated filter is appropriate to implement in RADAR communications networks.

D. Structure Design:

The recommended SIW filter system is designed using estimated parameters and simulation software numerical algorithms. Fig.1 represents the structure of SIW filter.

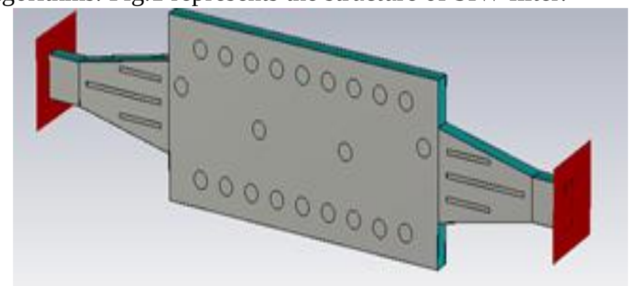

Fig.1 Substrate Integrated Waveguide (SIW) Structure

To Simulate and improve the filter a full wave electromagnetic simulation concept is achieved. Incorporating metallic holes with specific diameter and sufficient spacing in offset topology is the most efficient and significant approach. The framework of the SIW is prosecuted using a substrate with relative permittivity, 3.2 ε_r and 0.762 mm height.

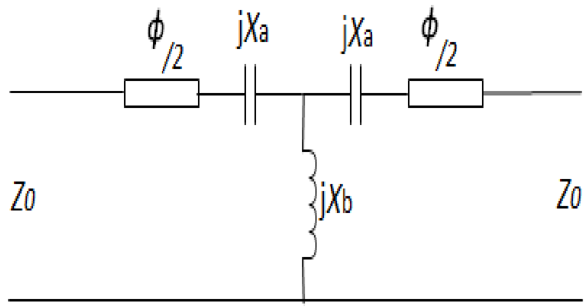

Fig. 2 Equivalent circuit of SIW post

Fig.2. describes the comparable metallic inductive post or vias T-network consisting of inductance, capacitance, and so on lumped components. Such inductive posts link each other to the SIW transmission lines. Xa and Xb are inductance and capacitance equivalents. The phase angle determined by means of the design equation given in [15],[16]. The length and width of the structure was suggested by means of design equations (1) ,(2), (3) and (4). The conceptual filter structure is energized by tapered topology of open-ended microstrip lines.

III. SIMULATED RESULTS

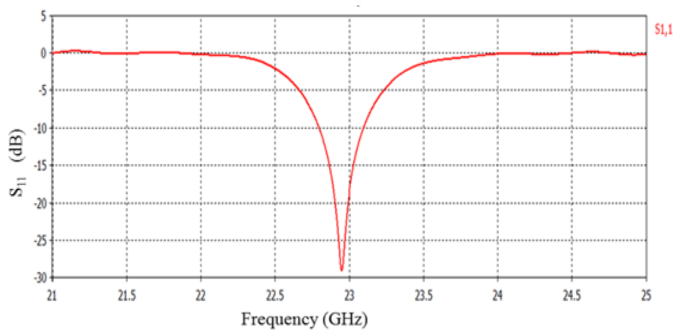

Fig. 3 Substrate Integrated waveguide Bandpass filter depicting S_{11} (return loss)

When the signal is moved from port 1 to port 2 the average return loss throughout the simulated frequency band is 0.2 dB. Fig. 3 and Fig.4 demonstrate the response of the Substrate Integrated Waveguide (SIW) Bandpass filter with respect to parameters S11 and S21. S11 reflects a 30 dB loss of return and a 0.06 dB loss of insertion (S21). The middle filter frequency is taken as 22.9 GHz. The tapered transitions of microstrips as feed lines are capable of bringing the low loss with sharp skirt features.

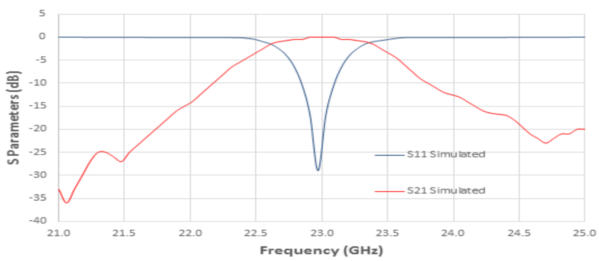

Fig. 4. The Substrate Integrated waveguide (SIW) Bandpass filter response

It represents that maximum return loss within the simulated frequency range is 0.1 dB.

IV. SIW FILTER FABRICATION AND MEASUREMENT

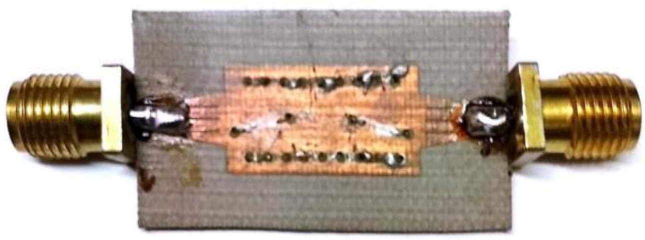

Fig. 5. Fabricated K-band Bandpass filter

Fig. 5 represents the fabricated view of the designed filter. The filter presented is developed using photolithographic procedures and tested using vector network analyser (VNA). Fig.6 shows that the simulated and measured results match well with one another. Similar to the design of Mona Sameri et al. in [16], the size of the designed filter is compact The filter is perfect for microwave and millimeter wave implementations. It is observed that two filters are developed, simulated and measured in K-band. The outcomes that are simulated and analyzed are in good agreement with each other. Now to satisfy the demands of the modern era of networking, it is important to change filters designing to further enhance the responses.

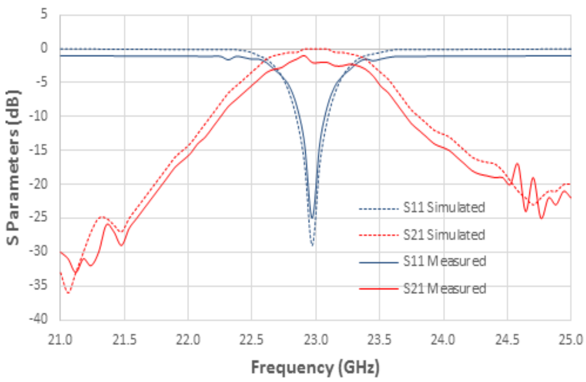

Fig.8. Measured and simulated results of Chebyshev filter using offset inductive posts

V. CONCLUSION

In this paper, a proposed filter is designed using Substrate integrated waveguide (SIW) technology. The offset post SIW filter is designed to work well in K-band. Due to tapered transition and inductive slots in transition, filter exhibit sharp roll off attributes and low losses. The filter developed using SIW technology is more effective, easier to manufacture compared to structures of waveguides and easier to interface with several other printed circuits.

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Dr. Aman Dahiya has received B.E & M.Tech degree in Electronics and Communication Engineering from Maharashi Dayanand University, Rohtak, India in 2005 and 2010 respectively. She has completed her Ph.D. degree in Microwave Engineering in 2019. She is having more than 13 years of work experience and currently working as an Assistant Professor in Department of Electronics and communication Engineering at Maharaja Surajmal Institute of Technology, New Delhi. Her research area includes microwave and millimeter-wave circuits and published many research papers in various reputed national and international journals .