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Modeling and Design of Microstrip Line Based SIW and Structural Effect on Wave Propagation Characteristics

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Abstract: ***The model of substrate integrated waveguide (SIW) has been analyzed and designed to investigate the effect of geometrical shape on propagation characteristic. Parameters that have been evaluated in this work are electric field, return losses and the transmission gain. Printed circuit board (PCB) is used as dielectrics to evaluate the results in the frequency domain of 6 to 11 GHz. FEM based method is applied to optimize the design of SIW device. The results obtained had shown that gain increases with the increase in frequency upto 9.75 GHz and correspondingly the return loss is minimum at this frequency.***

Keywords: SIW, FEM, Return Loss, Transmission Gain.

1. Introduction

Microstrip lines (MSL) are widely used in microwave systems because of its low cost, light weight, and easy integration with other components. Substrate integrated waveguides (SIW), which inherit the advantages from traditional rectangular waveguides without their bulky configuration, aroused recently in low loss and high power planar applications. SIW has emerged as a new mm wave integrated circuits and systems for the next generation technology due to their manifold advantages [1-5]. A waveguide based on SIW (shown in Fig. 1) is considered as a dielectric filled rectangular waveguide whose metallic walls are formed by cylindrical via arrays with specific diameter and separation between vias known as pitch. SIW yields high performance from very compact planar circuits [2].

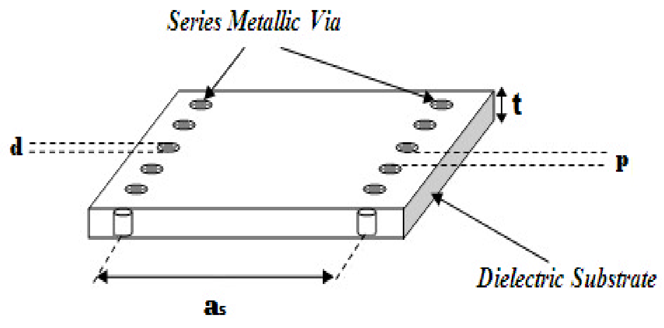


Figure 1. Basic SIW Structure.

Structure of SIW composed of the top and bottom metal planes of a substrate and two parallel via fences in the substrate. In order to replace the vertical metal walls, via pitch must be small enough [6-10]. The vias must be shorted to both metal planes to provide vertical current paths otherwise the propagation characteristics of SIW will be significantly degraded [11]. Unlike in conventional waveguide vertical metal walls are replaced by via fences for the SIW structures, propagating modes of SIW are very close to, but not exactly the same as, those of the rectangular waveguides [12]. SIWs are based in the TE modes, which preserves the characteristic of conventional waveguides and the propagation of energy of these modes is substantially limited in the substrate, which provides higher Q-factor and lower loss than other planar guided-wave structures.

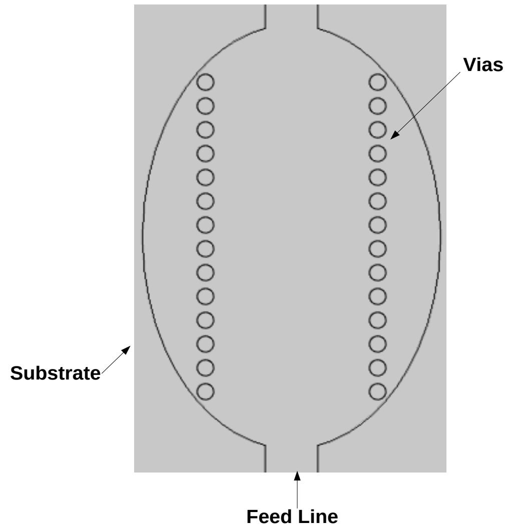


Figure 2. Structure of designed SIW

In fact, conventional planar resonators provide a moderate unloaded Q-factor, typically less than Q <100-200, while SIW resonators can reach a Q-factor higher than 500 using low-loss substrates. Furthermore, a growing interest has also focused on SIW technology because they can be easily integrated with microstrip or coplanar waveguide circuits on the same laminate [13-16]. In this paper FEM based modeling and design of SIW structure having elliptical structure is carried out.

2. Design and Analysis

Research work is carried out to simulate the effect of SIW structure with curved walls on the characteristics of the wave propagation using FEM based software. The dimensional parameters of the SIW taken in the experiment are shown in Table 1.

Table 1: Parameters of designed SIW

Parameter	*Dimensions (mm)*
Substrate thickness	60
Feed line width	3.2
Feed line length	30
Vias radius	0.5
Ellipse semi axis (a)	9
Ellipse semi axis (b)	13
Substrate (L x B)	30 x 20

Schematic of the design SIW structure is shown in Fig. 2. After designing the SIW structure, the whole schematic was extruded with thickness of 60 mm with air as the radiating environment shown in Fig.3.

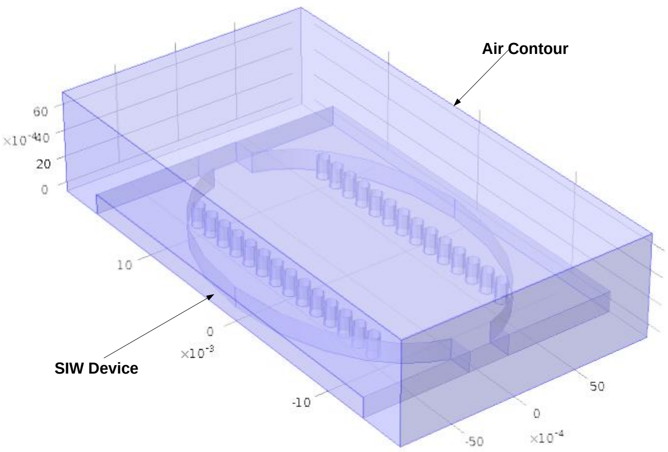


Figure 3. 3D view of the SIW structure and air contour.

3. Results and Discussions

Figure 4 shows the mesh design of a SIW model. Normal meshing is conducted on the SIW structure. The maximum element size selected for air contour taken is 5 mm and maximum element size for SIW structure is 3 mm. The design was simulated on the computational machine having 3.4 GHz processor speed.

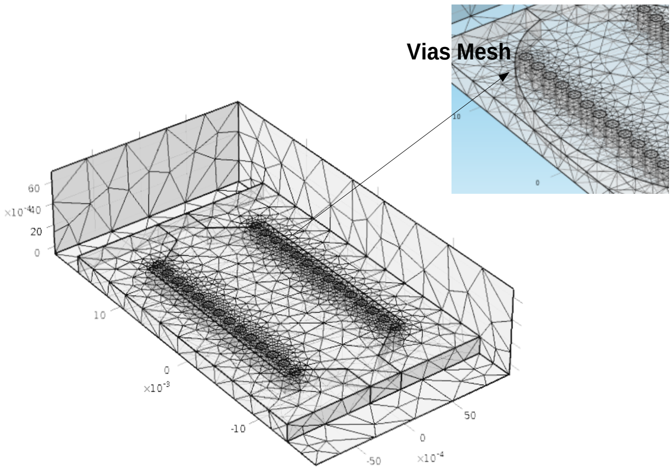
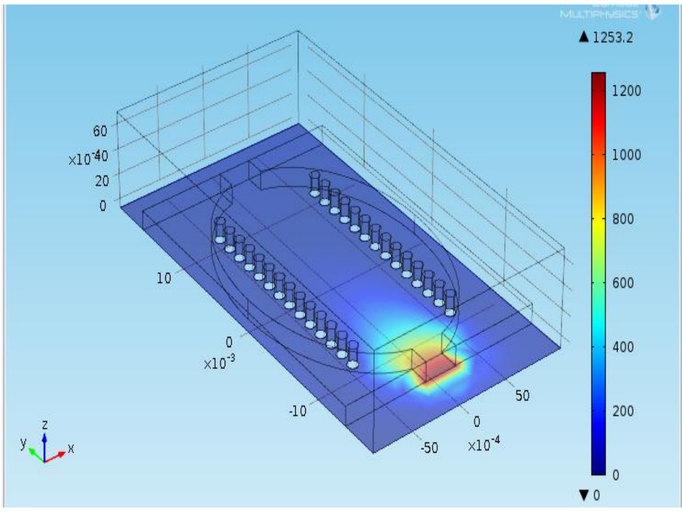
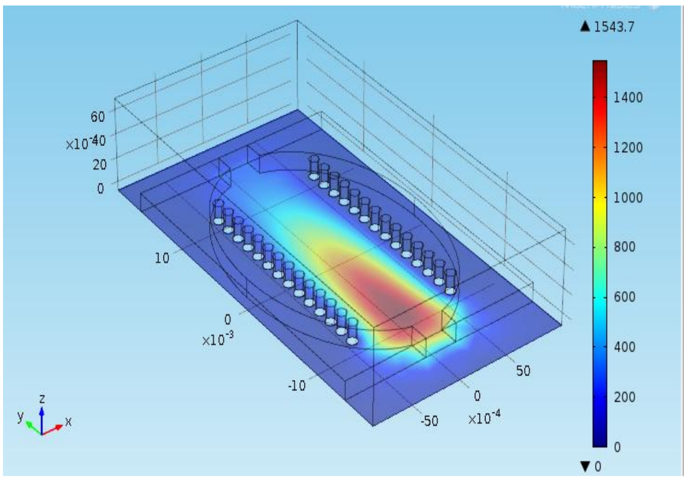


Figure 4. Mesh formation of SIW structure and air contour.

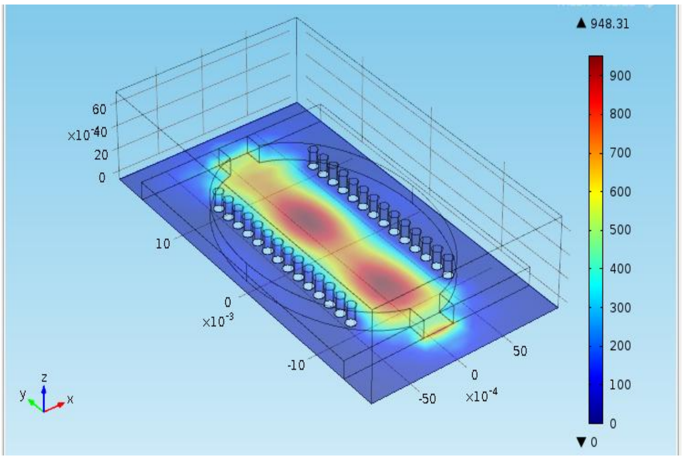
The virtual memory used while simulation was 2.97 GB. Normal meshing is selected to reduce the computational load. Frequency domain analysis of the SIW structure was carried out with minimum and maximum frequency of 6 GHz and 11 GHz and 0.25 GHz step size was chosen. EM wave propagation characteristic was obtained and shown in Fig 5. (a-c).



(a) 6 GHz



(b) 8.5 GHz



(c) 11 GHz

Figure 5. Electric field propagation at different frequency (a) 6 GHz, (b) 8.5 GHz, and (c) 11 GHz.

Return losses or input reflection coefficient (S_{11}) and the forward transmission gain (S_{21}) were plotted shown in Fig. 6. Dip in the return loss is observed at 9.25 GHz and transmission gain increases upto 9 GHz and then saturates.

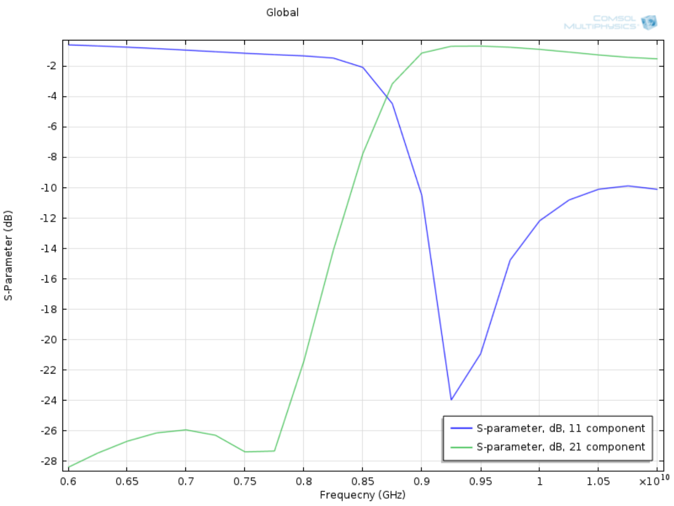


Figure 6. S_{11} and S_{21} (dB) for SIW device.

4. Conclusion

Simulated experiment work is carried out to investigate the effect of shape of the SIW on the electromagnetic wave propagation characteristics. S-parameters such as return loss and transmission gain were calculated for frequency ranging from 6 GHz to 11 GHz. It can be concluded that the SIW works efficiently at around 9 GHz.

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