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Research Article

Performance Evaluation of Substrate Integrated Waveguide based Antenna by Altering the Via Shapes

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Abstract

In this work, six antenna models based on substrate integrated waveguide (SIW) technology has been designed and analyzed to investigate the effect of via shapes on its operating parameters. Different parameters that have been evaluated in this paper are electric field, return losses and the transmission gain. The results were evaluated while selecting the frequency domain in-between 6 to 11 GHz. A sequential design steps were followed to design the finite-element method (FEM) based antenna models of the SIW structure. The results obtained had shown that the bandwidth and resonant frequency of the designed antennas remain static but the overall gain changes with the change in the shape of vias.

Keywords: *Substrate integrated waveguide, insertion loss, operating bandwidth, antenna gain.*

1. Introduction

Substrate coordinated waveguides (SIWs) based advancements are generally used on the grounds that they are effortless to create and any shape of slotted patterns can be drawn on the top surface. Subsequently, SIW predicated technology has been proved to be a rising and exceptionally encouraging contender for the advancement of circuits and segments working in the microwave and millimeter-wave area (R.C. Daniels *et al*, 2007; W.J. Fleming, 2008; L. Yujiri *et al*, 2003; J.H. Lee *et al*, 2005). SIW structures are usually manufactured by using two columns of leading barrels or spaces inserted in a dielectric substrate that interfaces two parallel metal plates, and endorse the usage of established rectangular waveguide segments in planar frame, along with printed hardware, dynamic creations and antennas (R.S. Elliot, 1983). The organization of mm-wave advances is basic for the development of remote frameworks as broadband and high determination procedures are normally sustained by the usage of mm-waves. In a large portion of these frameworks, the thriving predominantly relies on upon the accessibility of a cost-viable innovation, harmonious for the mass-engenderment of segments and frameworks (Y. Ding *et al*, 2007). It is normal that high-thickness joining procedures, mixed with a minimal effort creation process, ought to have the capacity to offer boundless answers for mm-wave business applications (M. Bozzi *et al*, 2011). SIW structures show spread qualities likened to the ones of traditional rectangular waveguides, including the field design and the scattering attributes (J. Hirokawa *et al*, 1998). Besides, SIW structures safeguard, the greater part of the upsides of regular metallic waveguides, in particular brilliant component and high power-taking care of capacity with self-reliable electrical protecting. The most important preferred standpoint of SIW innovation is the likelihood to coordinate every one of the parts on a similar substrate, including latent segments, dynamic components and even antennas (W. Che *et al*, 2008).

Initially created with the assignment of post-divider waveguide or overlaid waveguide for alimenting systems in radio wire exhibits, the SIW innovation has been connected to a few microwave parts, including post and depression channels, directional couplers, oscillators, control enhancers, slot array and leaky antennas, six-port circuits and circulators (M. Bozzi *et al*, 2011; L. Yan *et al*, 2004). From the specialized writing, it is outwardly seen that a large portion of the traditional waveguide segments have been actualized in SIW innovation. By the by, a large portion of these SIW parts work in the recurrence run up to 30 GHz, with a couple of special cases at higher recurrence (F. Xu *et al*, 2005; L. Qiang *et al*, 2011; A.J. Farrall *et al*, 2004). This marvel is not because of physical hindrances of SIW parts, but rather to the augmented innovative challenges experienced in outlining and assembling SIW structures over the mm wave go, to be specific, scaled down measurements, higher losses and

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the objective to scrupulously winnow the material (D. Stephens et al, 2005). Therefore, momentum and future research action intends to surmount these troubles, with a specific end goal to use SIW innovation as an interconnection and combination stage for mm-wave frameworks.

In this work, the structure of basic SIW is altered by changing the shapes of vias and the performance of the simulated SIW based antennas are evaluated for six different designs.

2. Experiment

Different designs were considered, simulated and analyzed to obtain the necessary output parameters of the proposed SIW antenna. The frequency range selected for analysis is in-between 9.2 GHz to 9.4 GHz.

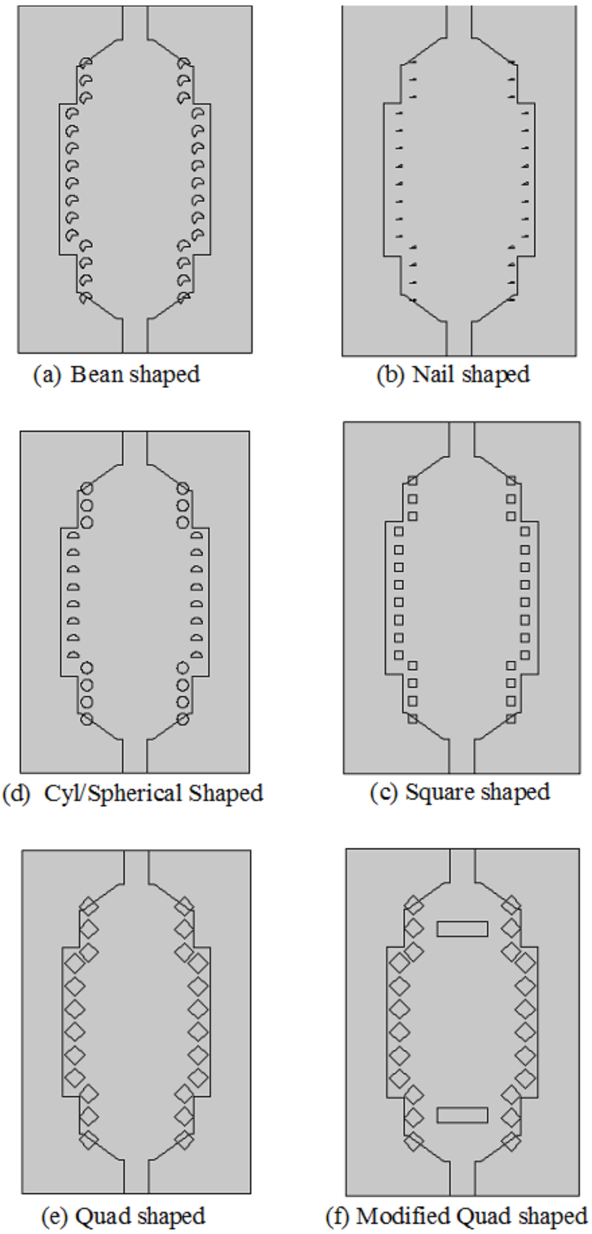

Fig.1 Design of different SIW based antennas with different via shapes

Since PCB based SIW antenna shows good performance than the other designs, hence it is selected to carry out further work. Thus, in our subsequent experiments, different shapes of vias were selected to investigate the antenna's performance. Fig. 1 shows the designed structures of an SIW consisting of the top and bottom planes of a substrate and two parallel via fences in the substrate. The vias are composed such that only patterns with vertical current distributed on the side wall can survive in SIWs. The models were designed in a FEM based COMSOL Multiphysics software using electromagnetic, frequency domain solver. A range of frequency from 6 GHz to 11 GHz is applied through the lumped ports to analyze the results for different SIW designs.

3. Results and Discussions

The whole structure is enclosed in the spherical domain to evaluate the antenna performance. The atmosphere fed inside the spherical domain is air.

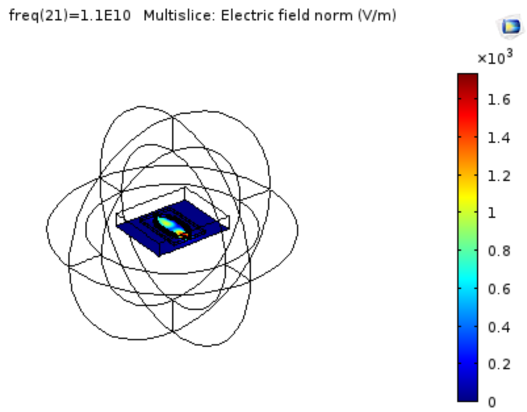

Fig. 2(a)

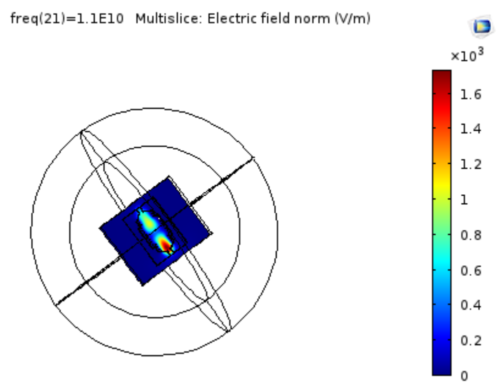

Fig. 2(b)

The purpose of such domain is to provide the atmospheric environment and to evaluate the results as practical as possible. Normal meshing is applied on the SIW structures. The maximum element size selected is 0.00375.

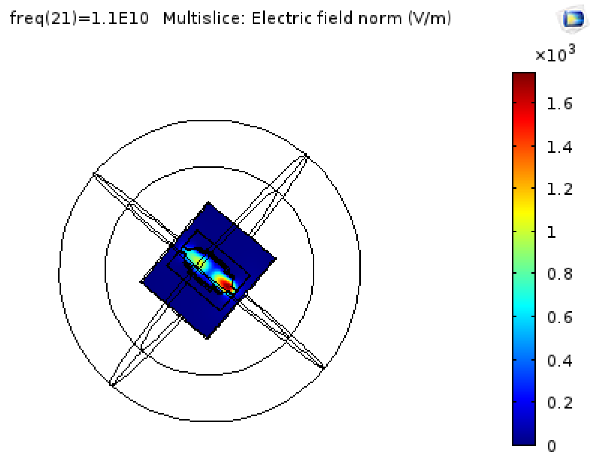

Fig. 2(c)

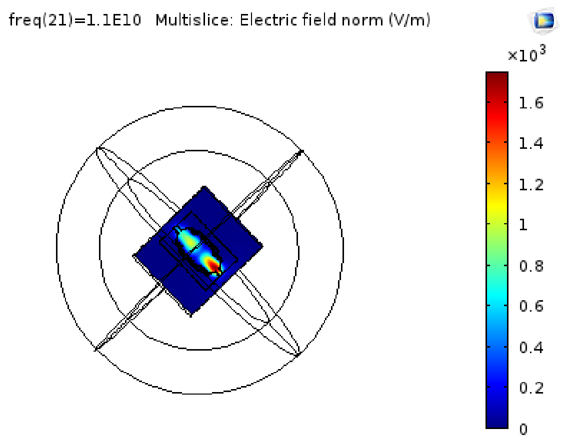

Fig. 2(d)

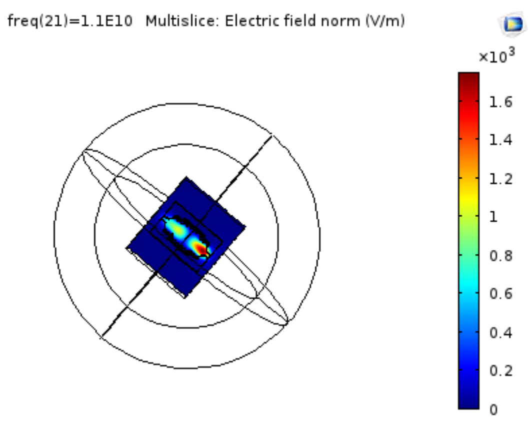

Fig. 2(e)

The design was simulated on the computational machine having 3.4 GHz processor speed. The virtual memory used during simulation was 2.1 GB. Normal meshing is selected to reduce the computational load. The electric field generated while computing the results for different via shapes are shown in Fig. 2.

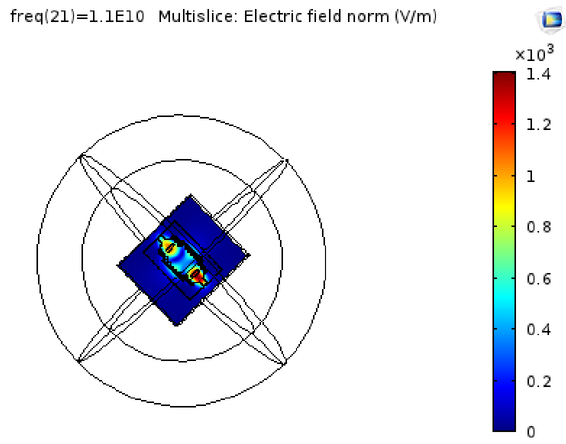

Fig. 2(f)

Fig.2 Electric field generated for different SIW based antennas.

Fig. 2(a) shows the simulated electric field for bean shaped via, while fig. 2(b) to 2(f) shows the radiations due to electric field generated for vias taken as Bean shaped, nail shaped, square shaped, cyl/hemi-spherical shaped, quad shaped and modified quad shaped respectively. From the bar line adjacent to these graphs it is clear that the maximum value (1.6 KV/m) of electric field is achieved for all the designs except the last one for which the maximum value of electric field is 1.4 KV/m.

Similarly the plot shown in figure 3 indicates graph between S-parameters and the frequency.

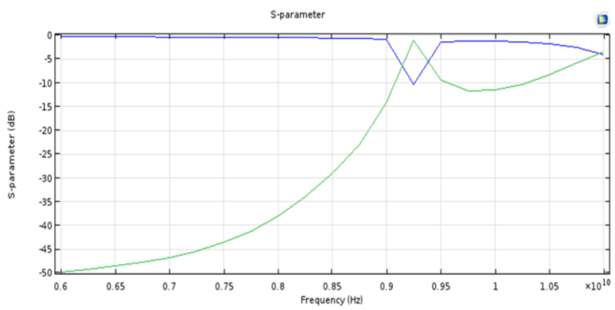

Fig. 3(a)

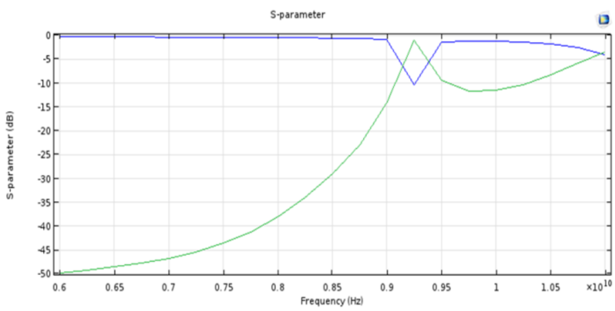

Fig. 3(b)

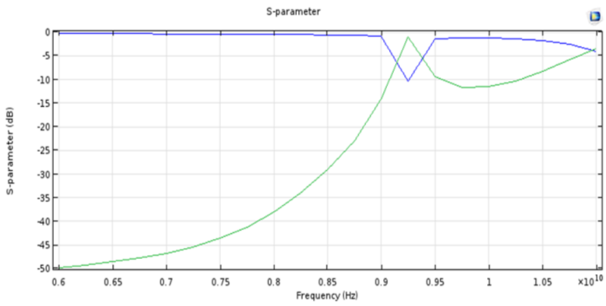

Fig. 3(c)

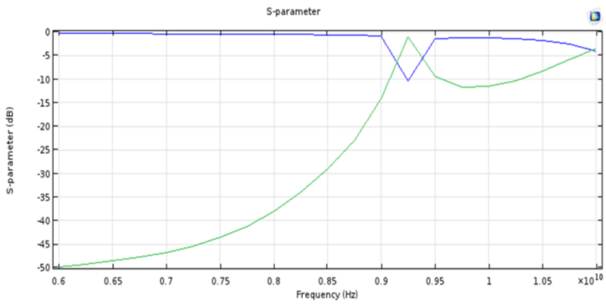

Fig. 3(d)

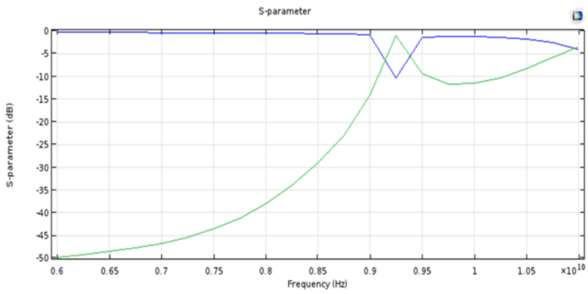

Fig. 3(e)

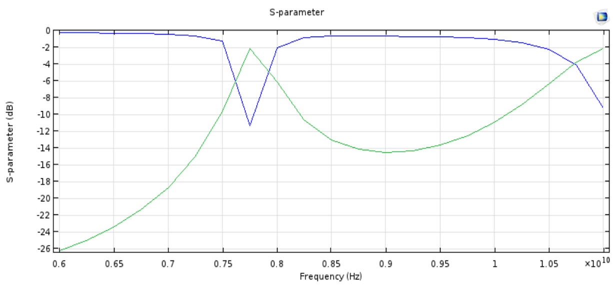

Fig. 3(f)

Fig.3 Insertion losses estimated for different SIW based antennas.

Return losses or input reflection coefficient (S11) and the forward transmission gain (S21) were plotted for all the different vias investigated for this experiment. Fig. 3(a) shows the S11 and S21 parameter w. r. t. frequency plot for bean shaped via. Dip in the return loss is observed at 9.3 GHz and transmission gain increases upto 9.3 GHz and then decreases for all the antennas. However for the last antenna design with modified quad shaped vias, the return loss is observed at 7.7 GHz and transmission gain increases upto 7.7 GHz and then decreases.

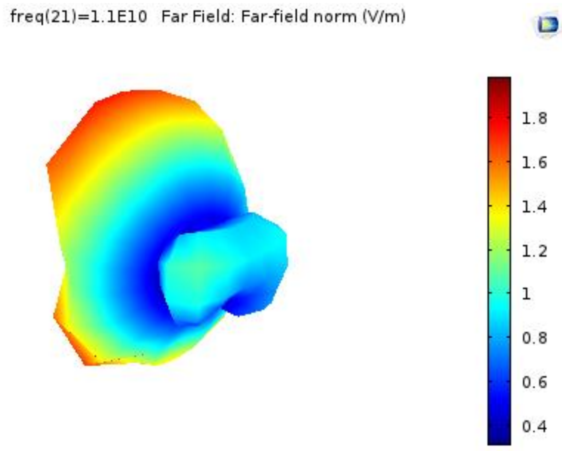

Fig. 4(a)

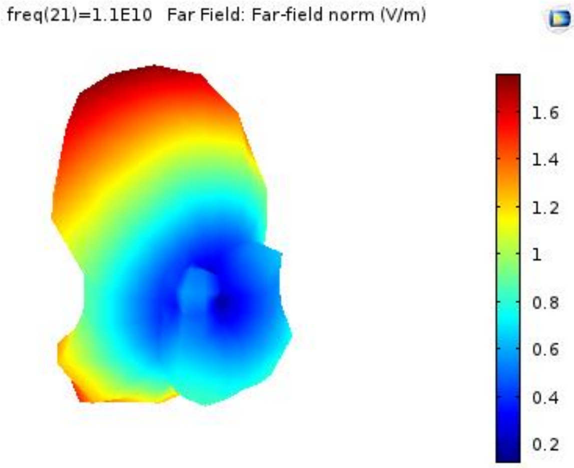

Fig. 4(b)

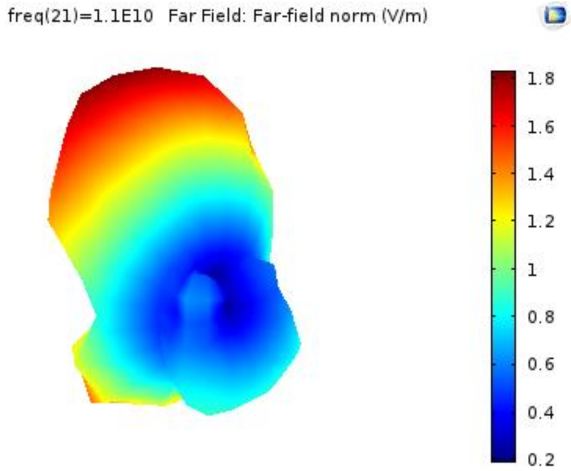

Fig. 4(c)

Fig. 4 shows the radiation pattern obtained while evaluation of results. The results showed that the simulated design comes with a subsequent gain for the entire frequency band especially at resonance.

However the gain is better for the antenna with cyl/spherical shaped via.

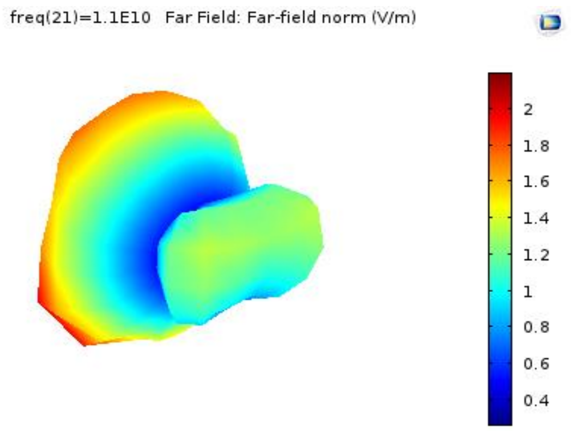

Fig. 4(d)

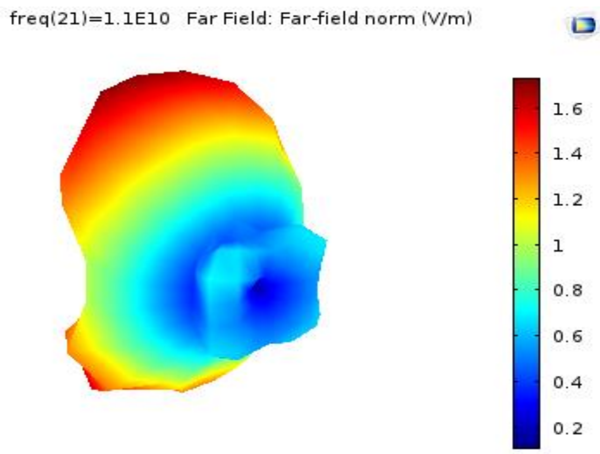

Fig. 4(e)

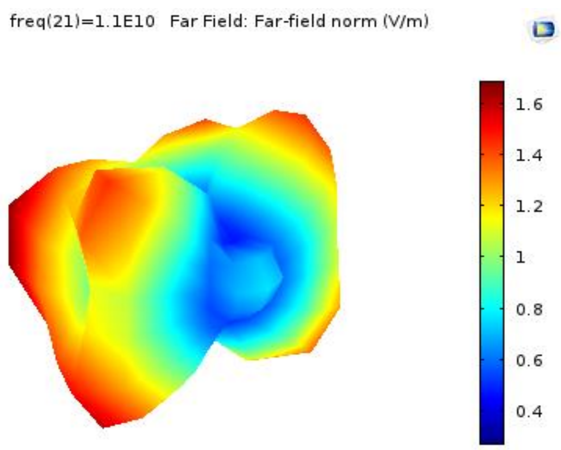

Fig. 4(f)

Fig.4 Radiation pattern estimated for different SIW based antennas

Similarly, Fig. 5 shows the polar plot obtained while evaluating the results.

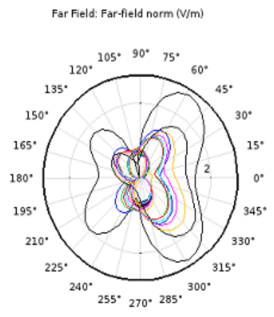

Fig. 5(a)

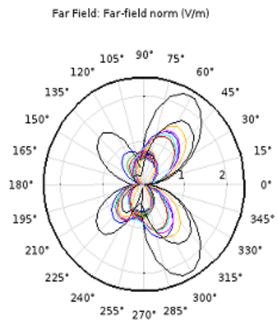

Fig. 5(b)

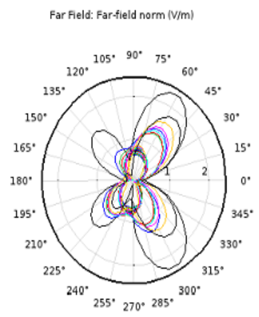

Fig. 5(c)

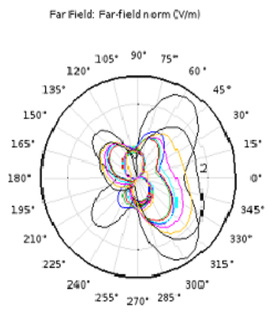

Fig. 5(d)

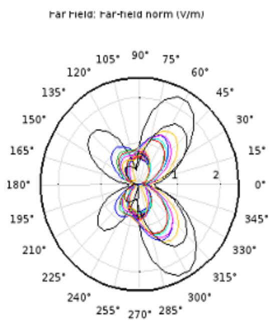

Fig. 5(e)

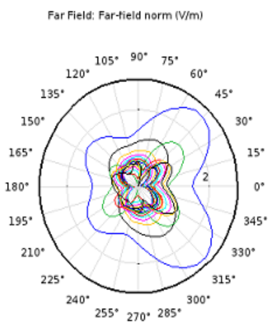

Fig. 5(f)

Fig.5 Polar plot estimated for different SIW based antennas

It is seen that the polar plots are more or less same for the simulated SIW based antennas. For the last selected antenna, the polar plot deteriorates in comparison to the other simulated antennas.

Conclusions

Simulation work is carried out to investigate the effect of different via shapes selected on the electromagnetic wave propagation in SIW. To evaluate the effect of via shapes, six different SIW based antennas were used in the experiment. S-parameters such as return loss and transmission gain were calculated for frequency ranging from 6 GHz to 11 GHz. Table 2 shows the comparative analysis of the results obtained for all the six different antenna designs. The bandwidth was obtained as 200 MHz for each antenna.

Table 1 Comparative analysis of different antenna designs on PCB substrate

Shape of via	Electric Field (KV/m)	Resonant Frequency (GHz)	Frequency Range (GHz)	Gain (dB)
Bean shaped	1.7	9.3	9.2 to 9.4	1.90
Nail shaped	1.7	9.3	9.2 to 9.4	1.70
Square shaped	1.7	9.3	9.2 to 9.4	1.80
Cyl/spherical shaped	1.7	9.3	9.2 to 9.4	2.10
Quad shpaed	1.7	9.3	9.2 to 9.4	1.70
Modified quad shpaed	1.4	7.7	7.6 to 7.8	1.70

Thus, in our experiments, we considered PCB design based SIW antennas and we altered the shape of vias in our designs. The results showed that the bandwidth and resonant frequency remain static but the gain of the antenna changes with the change in shape of vias. The gain was highest for the combination of circular and semi-circular vias, than the others. Also, in our last design, we introduced rectangular slots as impedance matcher. Due to this, we tried to convey that the intensity of the electric field becomes weaker from the input port to output port direction. Thus in overall, we studied SIW based antennas and investigated the impact of changes in shapes of via on the output parameters.

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