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Abstract. Recently, there has been increasing interest and rapid growth in millimeter-wave (MMW) antennas and devices for use in diverse applications, services, and technologies such as short-range communication,. It is important to design millimeter-wave antennas with high gain characteristics due to their high sensitivity towards atmospheric absorption losses. Moreover, millimeter-wave antennas can have wide bandwidth and are suitable for 5G applications. In this paper, planar antennas are designed using substrate integrated waveguide (SIW) technology to have low losses, high-quality factor, and low fabrication cost. The SIW array antenna achieved high gain 11.4 dB with high directivity 11.7dB and it achieved wider bandwidth almost 2GHz the bandwidth of the main structure achieved the requirement of 5G application.

Keywords—SIW, Millimeter wave and 5G application.

Introduction

In recent years, substrate integrated waveguide (SIW) [1–3] technology has gained more and more attention in the microwave community for its flexibility in the realization of microwave circuits [4]. The requirement of 5G communication network needs very wide band and high data rate, the frequency for the transmission antennas should be at millimeter wave frequency to be suitable for the satellite and mobile communication. The Ka band frequency in the millimeter wave is suitable and interesting range for the new applications in communication system especially in the antenna that used in vehicles**.** for Ka band systems there are many applications such as weather radars and fire detection radar work on Ka band range, the requirement of this systems are very wide bandwidth to try cover the Ka band with high directivity to be able transmit the wave signal with high gain and directivity to the receiver with the same power in the all frequency range and an automatic tracking system to catch the maximum power that come from the satellite while the time and position of the receiver changed Array antennas have many applications in communications systems.

Typically they developed by using kind of antennas such as micro strip or waveguide that it have good specifications. however, with this development but each of it has some not in demand specification for higher frequency, the new technology called substrate integrated waveguide (SIW) comes with in demand specification for higher frequency, several advantage comes with new technology such as low cost, and able to integrate with other planner circuit and the size small, [5] due to the several advantage that comes with SIW technology which suitable for millimeter wave frequency can consider it as new concept for the 5G application. SIW technology comes by depend on the waveguide technology, [6-7].

In this paper signal antenna operate in Ka band application have been done, the results of this signal got optimize by make the structure of single antenna as array antenna 1×4, the dielectric substrate that used of the structure is RogerRT 5880, a thickness of it 0.508mm with permittivity 2.2 and loss tangent 0.0009, the structure of this paper have been done by using CST simulation tool.

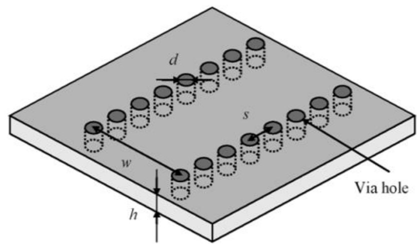

Figure 1: Basic SIW structure realized on a dielectric substrate.

Design SIW Antenna

As shows in fig1 the SIW antenna structure is similar with a waveguide structure. Two rows of plated through holes embedded along the circuit board to electrically connect the top and bottom surfaces of the PCB function as vertical walls of a waveguide. The idea of substituting conductor walls of a waveguide by plated through holes on the PCB. The SIW's modes is very similar with a subset of the rectangular waveguide's modes,

Since SIW design generally works in TE_{10} mode, so here m=1, n=0. Therefore the equation for cut off frequency reduces to,

$$\boldsymbol{f = \frac{c}{2a}} \qquad (1)$$

For DFW (dielectric field waveguide) with same cut off frequency, dimension "a_d" is found by:

$$\boldsymbol{a_d = \frac{a}{\sqrt{\varepsilon_r}}} \qquad (2)$$

Having determined the dimension "a_d "for the DFW, can now pass to the design equations for SIW, which may be given as,

$$\boldsymbol{as = a_d + \frac{d^2}{0.95p}} \qquad (3)$$

Where, a is the total broad side dimension of the rectangular waveguide, (as) is the separation between via rows (centre to centre), (a_d) is the width of DFW, d is the diameter, p is the distance between two vias (as shown in Figure 1) and c is the velocity of light in free space. Also, TE and TM modes represent Transfer Electric Mode and Transfer Magnetic Mode respectively. The suffixes m and n represent number of half waves in the x and y direction considering z as the direction of wave propagation.
The cut-off frequency of the SIW can be obtained using the above design equations. In our design we focused on the Ka-band applications and in our case the antenna has been designed to resonant at frequency of 16GHz. The dimensions of the slots are important for the antenna to behave as a slot antenna. The dimensions of the slots can be obtained with the help of the following relations.

$$\boldsymbol{b = \frac{\lambda_o}{\sqrt{2}((\varepsilon_r+1))}} \qquad (4)$$

Dimension of *c* doesn't matter much but should be less than half of *b*. The gap between centre to centre of slots has been considered as $\lambda g/2$ whereas the gap between the last slot and the closing face has been taken as λg /4 (Figure 3). Table 3.1 refer to the parameters structure of SIW.

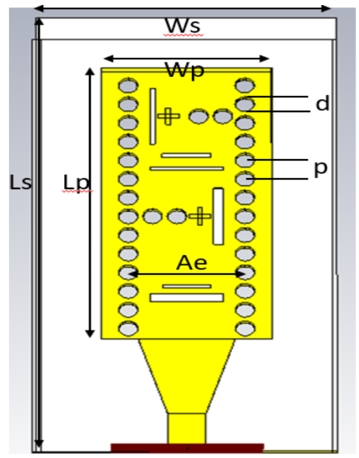

Figure 3 : Slot dimensions &gap between slots.

Table 1 refer to the parameters structure of SIW.

parameters	Value (mm)
Ls	14.1
Ws	12
P	1.1
d	1
b	1
h	0.508
Ae	4.80
Wp	7.12
Lp	7.5

The final structure as obtained after a microstrip to SIW transition with slots has been shown in Figure 3. The return loss of the slot structure as obtained has been shown in Figure 4 as orange color. The antenna has been found to resonant at 28 GHz with a return loss of 19dB. the signal with black color as shown in figure 4, it is refer to the same antenna but without slot, Can see how slot effect by shifting the return lose to the higher frequency.

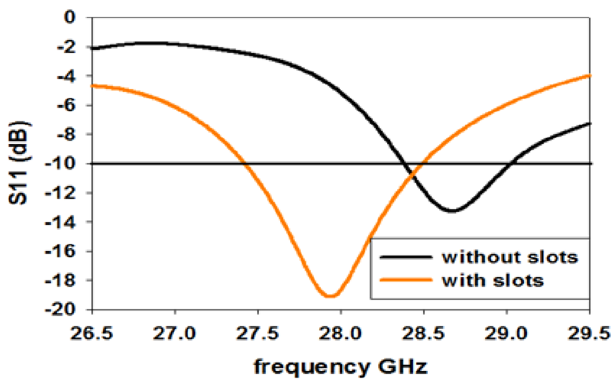

Figure 4 : S-parameter of SIW singal antenna.

2D radiation pattern of this single antennas can be seen in Figure 5. SIW antenna using Rogers RT5880 substrate RT5880 with thickness 0.508mm optimized gain, directivity and efficiency, as show in figure6.

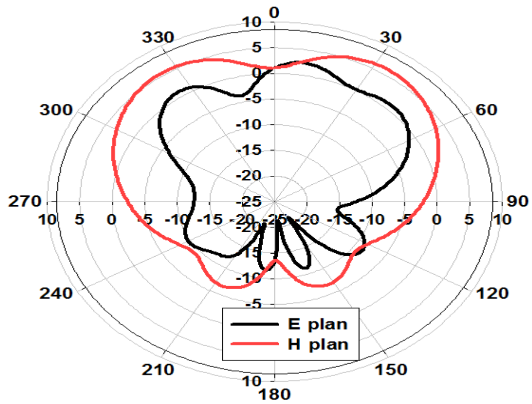

Figure 5 E and H plane of single SIW antenna.

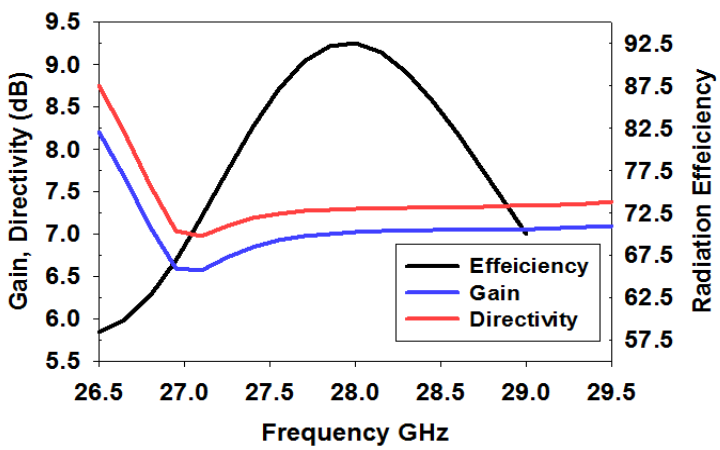

Figure 6: refer to the Gain, Directivity and Efficiency of single antenna.

Modify the singal antenna to the array antenna 1× 4 To show the characteristic and the effecting of reture lose, The sturcture of the singal antenna has been obtimized and lunch it to be array antenna 1× 4 as show in figure 6, The resonant frequncy of the array antenna at 28GHz and the returen lose of it became -23dB as show in figure 7.

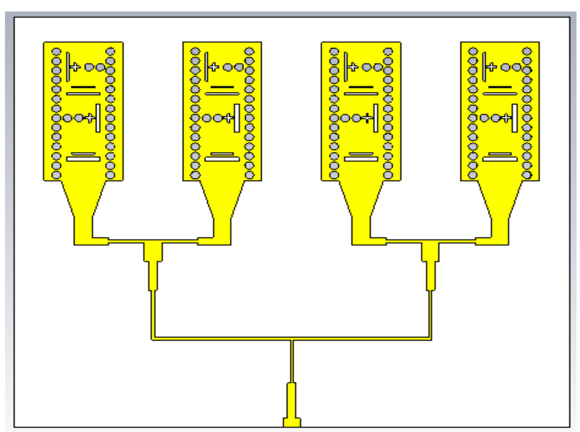
Figure 7: 1× 4 array antenna sutracture.

The determination of the S11 parameter was recorded at an operating frequency of 28 GHz operating frequency. It achieved -23 dB at 28 GHz with slot as can see in figure 7 with red color, below shows the S11 parameter which represents the return loss of 28 GHz antennae by using Rogers -RT 5880 as substrate. Which is below than -10dB for fulfilling the design specification. The obtained results of bandwidth are less than -10 dB (S11 < -10 dB) achieved around 2 GHz. the other signal that is shown in figure 8 with blue color refer to the array antenna without slot and can see the how the signal shifting to the higher frequency and the bandwidth decrease to less than 600MHz. figure 9 refer to gain, directivity and efficiency enhancement by using array method to the single antenna.

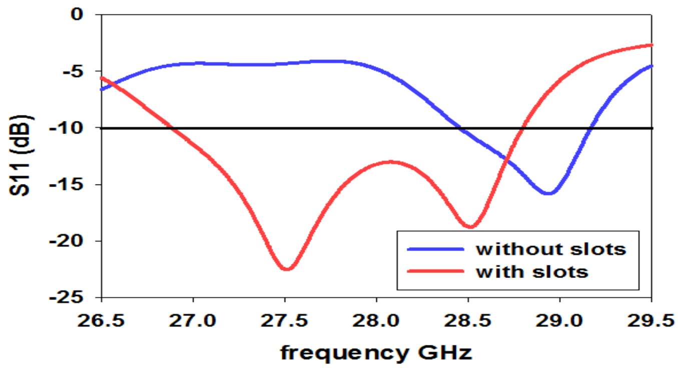

Figure 8: Return loss at frequency 28 GHz.

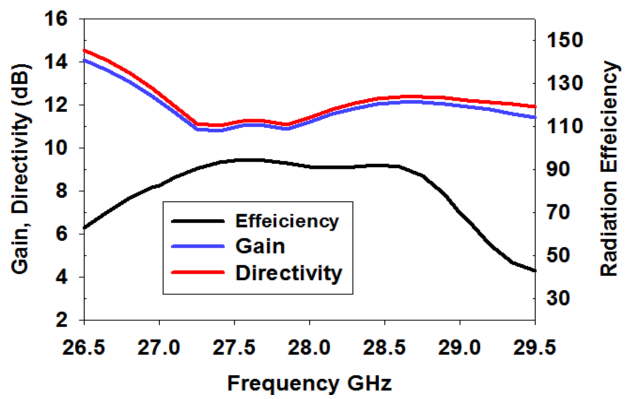

Figure 9: Gain, Directivity and efficiency of array antenna.

The radiation pattern

The variation of the power radiated antenna as a function of the direction away in the antenna far-field. The E-plane determines the polarization or orientation of the radio wave any plane that contains the E-field and the direction of maximum radiation from the antenna. Figure 10 shows the radiation pattern for frequency of 28 GHz.

The succeeding important parameter to analyze is radiation pattern characteristics. The characteristics includes the total gain that this antenna can radiate and also side lobe levels it exhibits in E-plane and H-plane respectively. The E plane is defined parallel to the feeding excitation, and H plane is as usual perpendicular to E-plane. As shown in figure10 the 2D radiation pattern of array antenna structure.

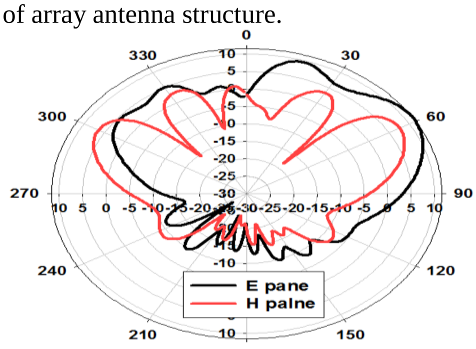

Figure 10: radiation pattern E and H plane.

Conclusion

In this paper SIW antenna have been done at 28GHz, for the higher frequency needs antenna with low loss and small size to be able use in millimeter wave application such as 5G application. The SIW antenna has low loss because of the vias at the edge of the antenna, the vias guide the signal in one direction and that means the SIW has more directivity. Substrate integrated waveguides are designed and simulated with CST program. The single antenna got gain 7.05 dB and the directivity is 7.6 dB with bandwidth more than 1GHz. The final structure as obtained after increase the element of the antenna and made it as array antenna 1× 4, the gain became 11.4dB, Directivity 11.7dB and the bandwidth achieved 2GHz, this result is suitable for 5G application because the antenna come with high date rate to make it able to cover many users. This result achieved the requirement of 5G application because of the gain and directivity comes with low loss.

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