A Shared Aperture Millimeter Wave Antenna Using 3D SIW Technology

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Abstract— A shared aperture millimeter wave antenna array based on three-dimensional (3D) substrate integrated waveguide (SIW) technology is designed for millimeter wave wireless communication applications. Dipole and slot antenna are used as elements and the two proposed antenna arrays work at 28 GHz and 75 GHz respectively. Both arrays use SIW H-to-E-plan vertical interconnect to form 3D architecture [1].

1. INTRODUCTION

With the development of wireless communication technology, the lower frequency spectrum is becoming more and more crowded. To solve this problem, millimeter wave wireless communication has been studied for many years, since it has many advantages, such as large capacity of communication, high quality of transmission and high confidentiality

In this paper, a shared aperture antenna using 3D SIW technology is proposed. Because of the narrow spacing between the 75 GHz element, the 28 GHz dipole array is placed in the vertical plane while the 75 GHz slot array is placed in the horizontal plane. A 1/8 and a 1/4 power divider are designed to feed the two arrays respectively. SIW H-to-E-plane interconnect is used to form a 3D power divider structure. Rogers RT/Duroid 5880 $\epsilon_r = 2.2$ with the thickness of 0.254 mm is adopted as substrate material in this design

2. SIW-FED SLOT AND DIPOLE ANTENNA

Figure 1 shows the geometric configuration of the proposed 75 GHz SIW slot antenna A transition structure is designed between the 50 Ω microstrip line and the SIW thus the quasi-TEM mode of the microstrip line can transform into the TE_{10} mode in the SIW by the taper [2]. Considering the element spacing of the 28 GHz dipole, the width of the slot **W** is determined to be at an appropriate value to avoid the grating lobe of the lower frequency array. The diameter **D** of the metallized holes and the spacing **b** between the holes are determined by the rules formulated in [3]. The parameters of the slot antenna are listed in Table 1. Simulated return loss and radiation patterns are shown in Fig. 2. The return loss is better than −10 dB within the bandwidth from 73.2 to 79.6 GHz and the peak gain is 11.7 dB.

SIW-fed dipole antenna is used as the lower frequency element. The design procedures are similar with the quasi-Yagi antenna explain in [4], except that a dipole is chosen instead of the quasi-Yagi in order to reduce the height of the whole array. As shown in Fig. 3, the SIW is transformed to broadside parallel stripline to feed the dipole antenna. The Z axis is perpendicular to the SIW plane and the arm of the dipole lies along the X axis. The optimized parameters of the dipole antenna which operates at 28 GHz are given in Table 2. Fig. 4 presents the simulated return loss and radiation patterns. Multiple simulations shows that the impedance matching is mainly affected by the length of the broadside parallel stripline and the width of $\mathbf{W_{arm}}$. As shown in Fig. 4, the simulated return loss is better than −10 dB from 25.9 to 31.6 GHz and the maximum radiation direction is Z axis with apeak gain of 4.8 dB.

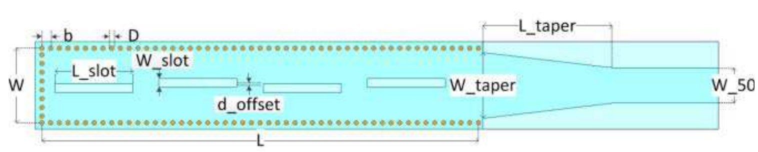


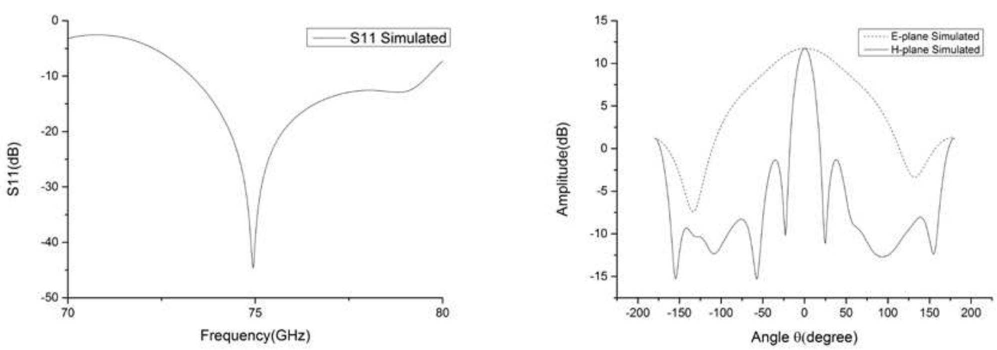
Figure 1: Geometric configuration of the proposed 75 GHz SIW slot antenna.

Table 1: Dimensions of the 75 GHz SIW slot antenna.

Symbol	Quality (mm)	Symbol	Quality (mm)
L	10	W_{slot}	0.1923
W	1.7	d_{offset}	0.0597
b	0.2	L_{taper}	3
D	0.1	W_{taper}	1.5
L_{slot}	1.7897	W_{50}	0.8

Table 2: Dimensions of the 28 GHz dipole antenna.

Symbol	Quality (mm)	Symbol	Quality (mm)
L_1	4.8	W_{50}	0.8
W_1	5.2	L_s	4.1018
b_1	0.4	W_s	1.6499
D_1	0.2	W_2	0.8
$L_{1\ \text{taper}}$	2.2024	L_{arm}	2.7291
$W_{1\ \text{taper}}$	1.818	W_{arm}	0.2147



(a) (b)

Figure 2: (a) Simulated return loss. (b) Simulated radiation patterns in both E-plane and H-plane at 75 GHz.

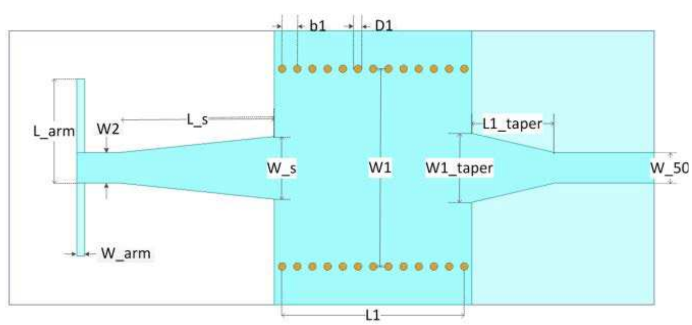
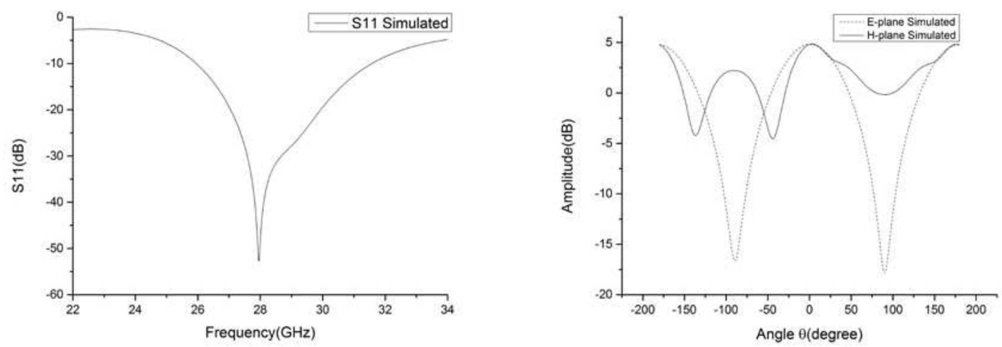


Figure 3: Geometric configuration of the 28 GHz dipole antenna.

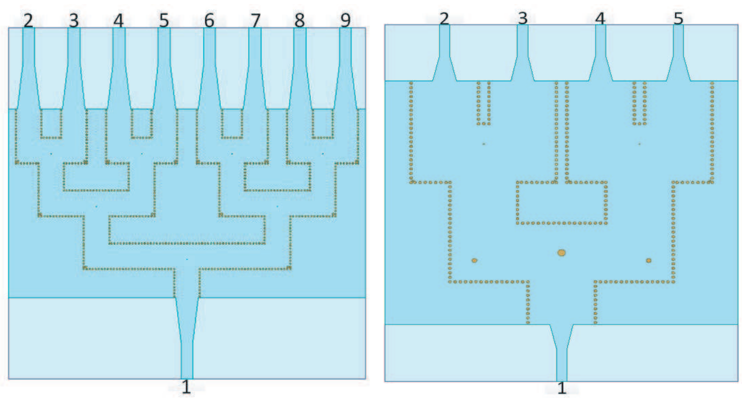
3. FEEDING NETWORK

Figure 5 shows the geometric configuration of the 1/8 and 1/4 power dividers. The 1/8 power divider is made up of T-junction power splitters and the 1/4 power divider is made up of one T-junction and one Y-junction [5]. Both Y- and T-junctions are equal power splitters to achieve the same amplitude distribution. The design of the SIW is the same as described above. Fig. 6 depicts the simulated frequency characteristics of the two power dividers, in which the simulated insertion loss is about 1 dB and 0.3 dB respectively.



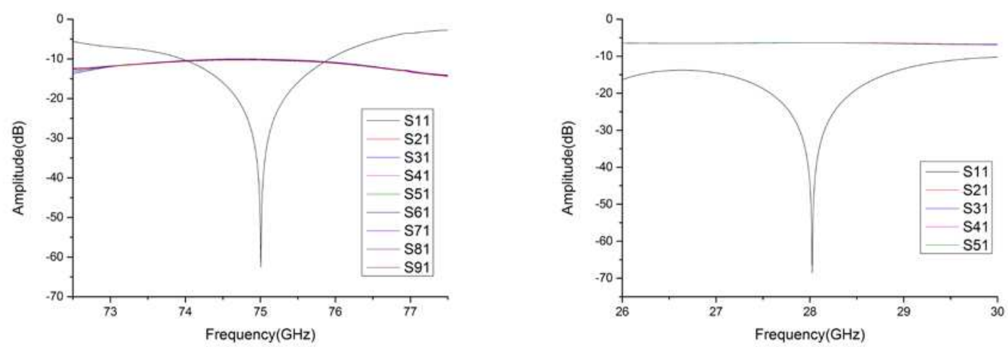
(a) (b)

Figure 4: (a) Simulated return loss. (b) Simulated radiation patterns in both E-plane and H-plane at 28 GHz.



(a) (b)

Figure 5: (a) 75 GHz 1/8 power divider, (b) 28 GHz 1/4 power divider.



(a) (b)

Figure 6: (a) 75 GHz, (b) 28 GHz simulated frequency characteristics of power divider.

4. ARRAY ANTENNA

The overall structure of the proposed shared aperture array antenna is described in Fig. 7. As for the 75 GHz array, the antenna elements are set in the horizontal plane while the power divider is set in the vertical plane. The 28 GHz array is just the other way around. There are two slot antennas between each dipole. Both arrays and their power dividers form 45 degree angle and connect with each other through SIW H-to-E-plane vertical interconnects. The simulated results are shown in Fig. 8. The return loss is better than -10 dB from 74.7 to 75.7 GHz and 26.3 to 29.1 GHz. The peak gain of the two arrays is 18.3 and 11.3 dB. The incision size on the slot array determined the amplitude of the 75G array's back lobe. The value of $\mathbf{L_{cut}}$ is optimized to be 4.5 mm to lower the amplitude of the back lobe to -3.5 dB. In comparison with Fig. 4(b), Fig. 8(d) indicate that the

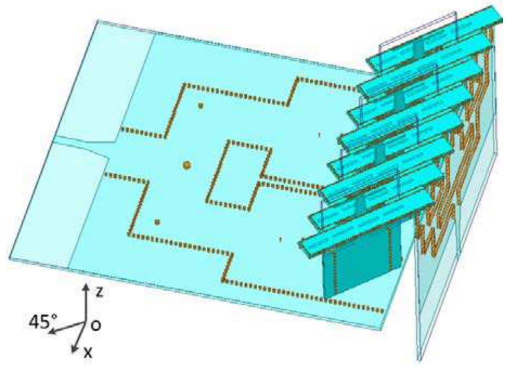


Figure 7: Geometric configuration of the shard aperture antenna.

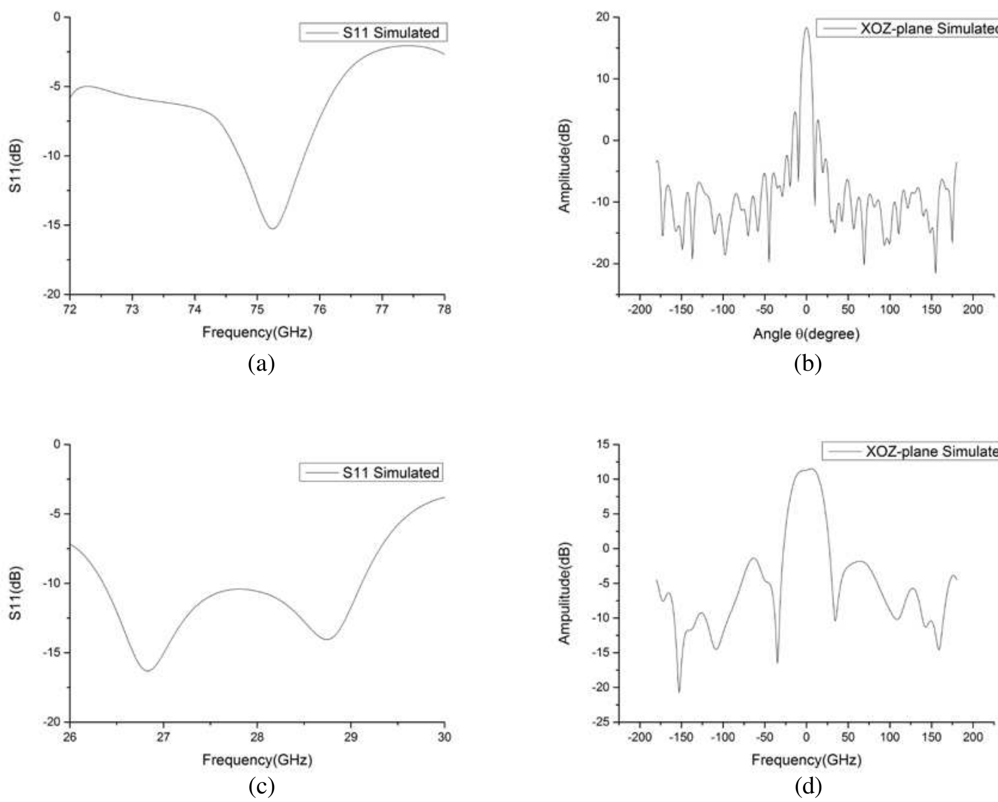


Figure 8: (a) Simulated return loss. (b) Simulated radiation patterns in XOZ-plane at 75 GHz. (c) Simulated return loss. (d) Simulated radiation patterns in XOZ-plane at 28 GHz.

dipole array antenna radiate toward the vertical direction because of the slot array antenna served as a ground. Both arrays can also extend in the 45° direction [6].

5. CONCLUSION

In this paper, a shard Aperture Millimeter Wave Antenna Using 3D SIW Technology is designed and simulated. The slot array antenna works at 75 GHz and has a peak gain of 18.3 dB while the dipole array antenna works at 28 GHz and has a peak gain of 11.3 dB. Simulated results show that both arrays can work properly, thus these arrays can be used to construct a columnar conformal array for millimeter wave communication.

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