

A SIW Fed Antipodal Linear Tapered Slot Planar Multi-Beam Antenna for Millimeter-Wave Application

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Abstract

In this paper, a millimeter-wave multi-beam antenna is studied by rotating the antipodal linear tapered slot antenna (ALTSA) with respect to a center is successfully designed. In order to lowering the SLL and enhancing the isolation between the ALTSA elements, a row of metallic via is inserted between the ALTSA elements. A 9 beams antenna is designed and experimented at Ka band. The measured and simulated results agree well with each other. The antenna can provide horizontal wide angle coverage up to $\pm 62^\circ$. The gain of each beam can achieve about 12.5 dB. The mutual coupling between ports is all below 20 dB.

Key words : Antipodal Linear Tapered Slot Antenna, Planar Multi-Beam Antenna, Gain, Mutual Coupling, Substrate Integrated Waveguide (SIW).

I. Introduction

With the development of communication technology, demands for high data rate, great capacity and wide range of mobility communications increase. Multi-beam antenna in one or two dimension has been widely used in the aircraft and communication link^{[1]~[4]}. Many kinds of multi-beam antennas have been investigated in the last few years, such as frequency scanning antenna, phased array antenna^[1] and lens antenna^{[2],[4]~[6]}. Frequency scanning antennas often use the leaky-wave antenna, the antenna direction of the main lobe varies with frequency, and generally the beam scanning range is small. Phased array antenna controls the direction of the antenna main lobe by adjusting the antenna phase of the input port. Generally the consistency between each beam such as gain, and beam pattern for the phased array antenna is not good. An ideal Luneburg lens is made up of a dielectric sphere with varying permittivity. It is difficult to be fabricated and the cost is expensive. Luneburg lens antennas consist of two parts: the feeding antennas and the lens. The two parts physically separate from each other and the lens generally are not planar and non-coplanar with the feeding antennas.

In this paper, a planar multi-beam lens antenna is proposed. The antenna elements adopt a set of antipodal linearly tapered slot antennas (ALTSA) fed by substrate integrated waveguide (SIW)^[7]. ALTSA elements are positioned around a circular and a row of metallic via is inserted

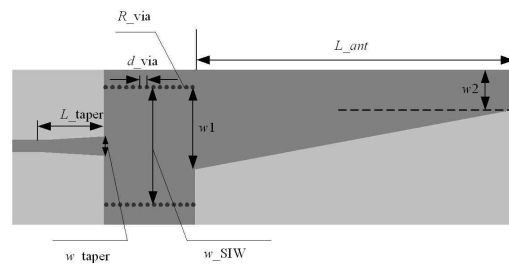


Fig. 1. Schematic of a SIW ALTSA.

between the ALTSA elements. The prototype is simulated and designed at 28 GHz, the antenna is fabricated on a single Rogers 5880 dielectric substrate with a thickness of 0.508 mm and a relative permittivity of 2.2. The measured results for the 9-beams antenna show advantages in many aspects such as low coupling between ports, beam consistency etc. The gain of the antenna is about 12.5 dB.

II. Simulation for the Antenna

In the past years, many papers have pay more attention to ALTSA for its salient performances such as narrow beam width, high element gain, wide bandwidth^[7]. Fig. 1 shows the top view of the ALTSA. All the parameters applied in the simulation are listed in Table 1. The ALTSA element is first simulated. The 3 dB beam width in horizontal plane is about 36° . The gain of the antenna is about 12.6 dB. The SLL is about 14.3 dB.

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Table 1. Parameters of the antenna element. (Units: mm)

L_taper	5.27	w_SIW	5.98	R_via	0.2
w_taper	1.8	d_via	0.6	w ₁	4.19
L_ant	46.91	w ₂	3.82		

Based on this ALTSA element, a multi-beam by rotating the element with respect to a center which positioned ahead of the antenna element is proposed. In order to lowering the SLL and enhancing the isolation between the ports, a row of metallic via is inserted between the ALTSAs which connect the metal upside and the bottom. This can greatly reduce the couple through substrate between antenna elements. A 9 beams antenna is designed. The angle between the adjacent beams is 15 degrees. The beam directions are designed as 60°, 45°, 30°, 15°, 0°, -15°, -30°, -45°, and -60° respectively. The antenna is fabricated on Rogers 5880 substrate with a thickness of 0.508 mm and a relative permittivity of 2.2. Fig. 2 shows the simulated return loss excited by Port 1 to Port 9. The frequency band with return loss below -15 dB is as wide as 8.5 GHz(22~30.5 GHz). Fig. 3 gives the mutual coupling. Coupling between ports are all below -20 dB. The mutual coupling between adjacent ports is the strongest one. The simulated radiation patterns in horizontal plane are shown in Fig. 4. The

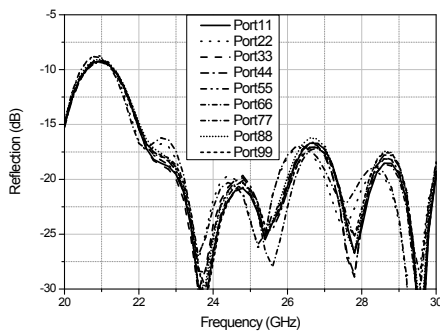


Fig. 2. The simulated return losses of the multi-beam antenna excited by ports: Port 1~9.

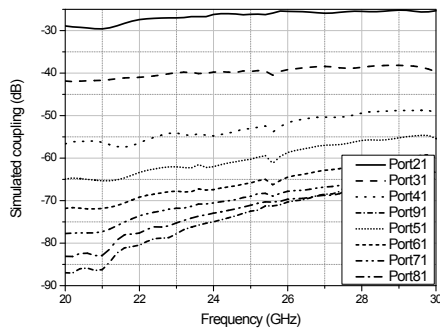


Fig. 3. The mutual coupling of the multi-beam antenna excited by Port 1.

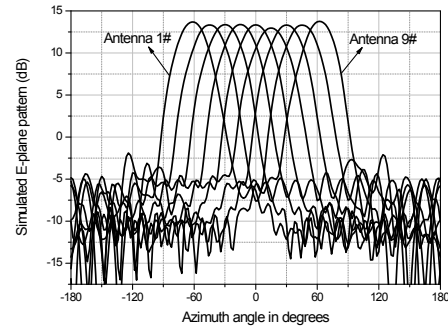


Fig. 4. The simulated E-plane radiation patterns of the multi-beam antenna at 28 GHz.

Table 2. The simulated gain and main direction for each beam.

Port	Port 1	Port 2	Port 3	Port 4	Port 5
Gain(dB)	13.69	13.32	13.36	13.37	13.34
Main direction (degree)	-62	-45	-30	-15	0
Port	Port 6	Port 7	Port 8	Port 9	
Gain(dB)	12.96	13.32	13.3	13.76	
Main direction (degree)	15	30	45	62	

main direction of the beam agrees with the design angles well in addition to excited by Port 1 and by Port 9 whose main direction of the beam has a small offset. All beams have almost the same radiation pattern and gain except for beams excited by Port 1 and by Port 9. The reason is that beams excited by Port 1 and by Port 9 are on the side of multi-beam antenna. The simulated gains and main directions of each beam for the multi-beam antenna are shown in Table 2.

III. Measurements

Depicted in Fig. 5 is a photograph of the fabricated multi-beam antenna, designed for 9 beam ports, and etched on a substrate Rogers 5880, 0.508 mm thickness, low loss tangent with relative permittivity of 2.2. The size of the antenna is about 215×101 mm².

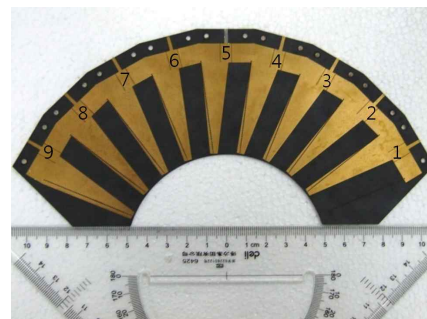


Fig. 5. Photograph of the multi-beam antenna.

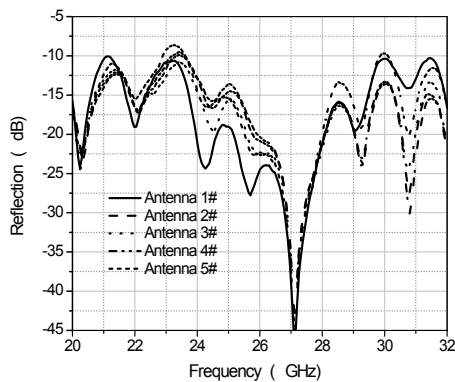


Fig. 6. The measured return losses of the multi-beam antenna excited by ports: Port 1~5.

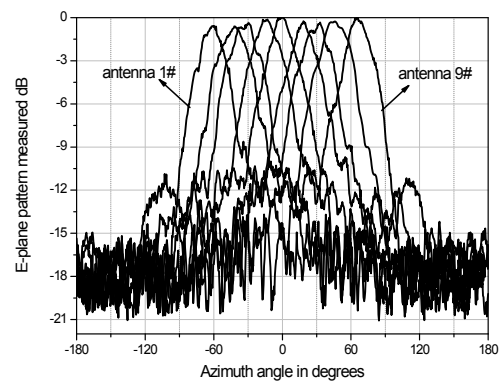
The multi-beam antenna has many important factors such as return loss, gain, mutual coupling (isolation) between ports, and beam uniformity. The return losses are shown in Fig. 6. The return losses and the mutual coupling coefficients are measured from 20 GHz to 32 GHz. The frequency band of 9 GHz (23~32 GHz) is achieved for all ports with return loss below -10 dB which are almost the same as simulation results except for a some higher level. Coupling between ports are all below -20 dB which is about 5~10 dB higher than that simulated.

Fig. 7 depicts the anechoic chamber experimental results of fabricated multi-beam antenna for 9 beams. These figures can be respectively compared to Fig. 4, above. It can be observed from this comparison that experimental results are almost identical to that of simulated results, in terms of scanning angle, beam gain, and side lobe levels. The radiation patterns at 28 GHz and 30 GHz are measured for each beam of the antenna. The main direction of each beam measured at 28 GHz are -60.5° , -42° , -29.3° , -17° , 0° , 18.4° , 33° , 46° , and 64° respectively. In Fig. 8 the gain of each beam at different frequency is measured. The gain is about 13.5 dB at 26 GHz, about 12.5 dB at 28 GHz, and about 12 dB at 30 GHz.

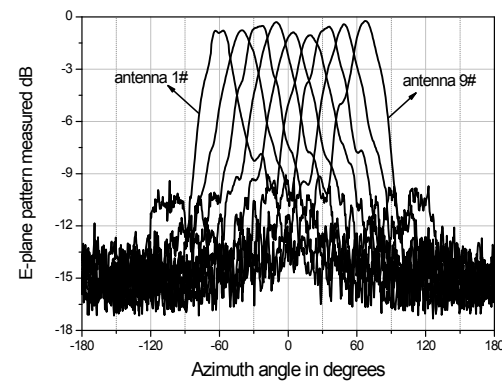
IV. Conclusion

In this paper, a simple multibeam antenna is successfully designed for operation in millimeter-wave frequency band. A 9 beams antenna has been designed and fabricated. Measured results are in good agreement with the simulation.

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(a)



(b)

Fig. 7. The measured gain of each beam for different frequency.

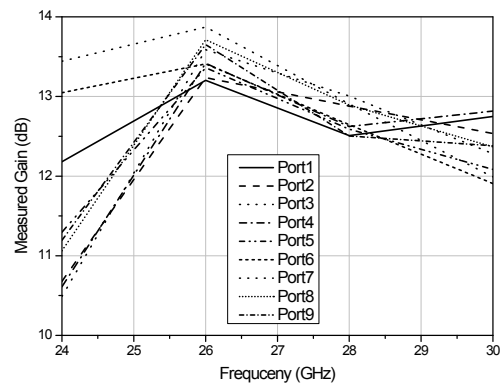


Fig. 8. The measured gain of each beam for different frequency.

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