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Evaluation of Fan Beam Carbon Fiber Reinforce Plastics Offset Parabolic Reflector Antenna for W-band Millimeter-Wave Radar Systems

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***Abstract* - This paper discusses an evaluation of a fan beam carbon fiber reinforce plastics (CFRP) offset parabolic reflector antenna for W-band millimeter-wave radar systems. For the radar applications with mechanical azimuth scanning systems, it is required to achieve a narrow azimuth radiation pattern, as well as a relatively wide elevation pattern. Firstly, the CFRP parabolic reflector, which has the aperture size of 327 mm × 300 mm, is fabricated using 1K woven fabrics. Next, the maximum gain and radiation pattern are measured between 75 GHz and 110 GHz. Finally, the CFRP parabolic reflector with the 15.0 mm-diameter conical horn feeding confirms elevation fan beam characteristics and a gain of almost 40 dBi at 96 GHz.**

***Index Terms* — Foreign object debris detection, Millimeter-wave radar, parabolic reflector antenna, W-band.**

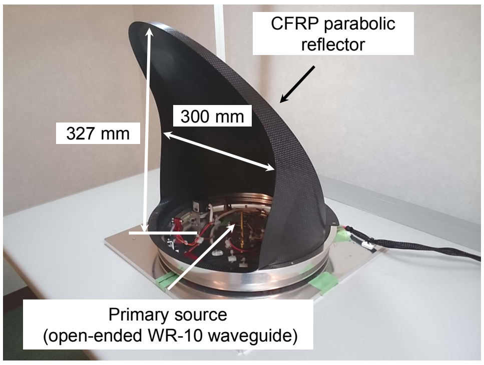

Fig. 1. Overview of the fan beam CFRP offset parabolic reflector antenna for W-band millimeter-wave radar system.

I. Introduction

To detect foreign object debris (FOD) on the airport surface, several types of runway surveillance systems have been developed. This is because a fatal aircraft accident was caused by small FOD on a runway [1]. In terms of high-sensitivity, high range resolution and weather robustness, millimeter-wave radar is a key device to detect such FODs. We have been developing the W-band millimeter-wave radar for FOD detection and other civil aviation applications [2], [3]. This paper discusses an evaluation of the fan beam offset parabolic reflector antennas using carbon fiber reinforced plastics (CFRP).

Firstly, the operation principle of the azimuth mechanical beam scanning offset parabolic reflector antenna is discussed. The CFRP parabolic reflector is fabricated and measured to obtain fundamental antenna characteristics. Next, the conical horns are employed as the primary source to achieve fan beam elevation radiation patterns.

II. Offset Parabolic Reflector Antenna

Fig. 1 shows the overview of the fabricated CFRP offset parabolic reflector antenna for the W-band millimeter-wave radar system. The antenna is the parabolic reflector made of CFRP using 1K woven fabrics. The CFRP enables the construction of a very light-weight and high specific-strength antenna. The primary source of the antenna is fixed on the top of the radar circuit. The parabolic reflector collects the horizontal incident wave and reflects it to the primary source which is located at the center of the rotation axis. The CFRP reflector mechanically rotates 360 degrees to scan the beam in the azimuth plane. Note that the position and the angle of the primary source cannot be changed since the focal point is the rotation axis of the azimuth plane.

The size of the CFRP parabolic reflectors is 327 mm × 300 mm (height × width). The characteristics of the 200 mm width CFRP offset parabolic reflector have been obtained so far [2]. To achieve an antenna gain of more than 40 dBi at 96 GHz, while maintaining the fan beam characteristics of elevation radiation patterns, the volume of the antenna is increased. Fig. 2 and Fig. 3 show the gain and radiation patterns of the antennas with open-ended WR-10 waveguide, respectively. The maximum antenna gain at 96 GHz is 42.8 dBi.

III. Conical Horn Feeding

The primary source is varied to experimentally investigate the effect on the antenna characteristics. The fundamental characteristics of the conical horn feeding are investigated by using FDTD analysis [3]. Fig. 4 shows the overview of the primary source including the open-ended WR-10 wave-guide and the conical horn antennas. The diameters of the conical

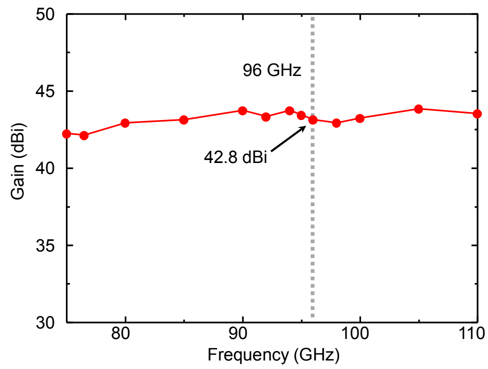

Fig. 2. Measured antenna gain with open-ended WR-10 waveguide feed.

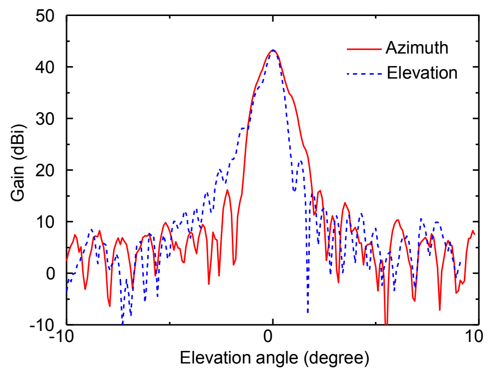

Fig. 3. Measured radiation patterns of the antenna at 96 GHz. (Primary source: open-ended WR-10 waveguide)

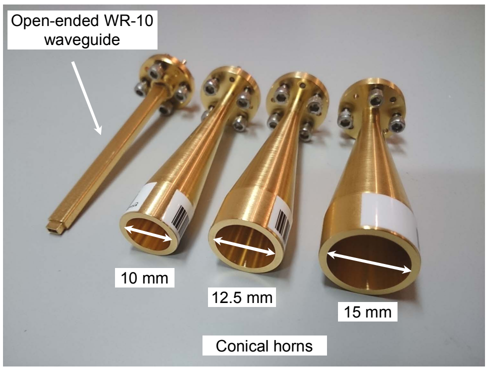

Fig. 4. Overview of the primary source including the open-ended WR-10 waveguide and the conical horn antennas.

horns are 10.0 mm, 12.5 mm, and 15.0 mm. The orientation of the primary source is fixed to the vertical polarization. Fig. 5 shows the measured radiation patterns of the antenna at 96 GHz, which employs the 15 mm-diameter conical horn. The asymmetrical pattern for the elevation angle is mainly due to the phase difference of the parabolic surface. By comparing Fig. 3 with Fig 5, broad radiation characteristics are observed for both azimuth and elevation patterns.

Table I summarizes the antenna gains and half-power beam width (HPBW) of each type of primary source. By increasing the aperture dimension of the primary source, fan beam characteristics for the elevation radiation patterns are achieved. The elevation HPBW with the open-ended WR-10 waveguide feeding is less than the azimuth HPBW. On the other hand, the elevation HPBW with 15.0 mm-conical

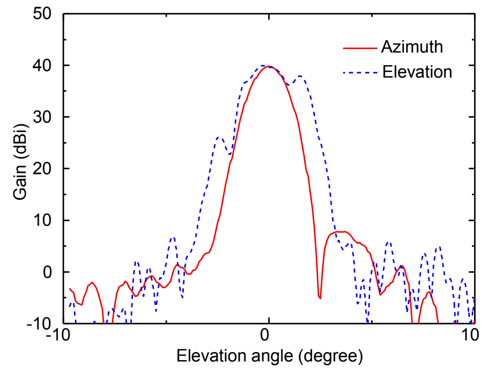

Fig. 5. Measured radiation patterns of the antenna at 96 GHz. (Primary source: 15 mm-diameter conical horn)

TABLE I
ANTENNA GAIN AND HALF-POWER BEAM WIDTH

Primary source	Gain (dBi)	Half-power beam width (degree)	
		Azimuth	Elevation
Open-ended WR-10	42.8	0.8	0.6
Conical horn 10.0 mm diameter	41.8	1.1	1.8
Conical horn 12.5 mm diameter	41.1	1.3	2.3
Conical horn 15.0 mm diameter	39.3	1.5	2.8

horn feeding is increased to 2.8 degree, which is almost double the width of the azimuth HPBW.

IV. CONCLUSION

The fabrication and measurement results of the CFRP offset parabolic reflector antenna for the W-band millimeter-wave radar was discussed. For the azimuth scanning antenna, the fan beam characteristics are required for the elevation radiation patterns. The measured results confirmed the fan beam characteristics of almost 40 dBi gain at 96 GHz. The optimization of the radiation patterns will be carried out based on numerical analysis.

ACKNOWLEDGMENT

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