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A Novel W-Band Dual-Polarized Cassegrain Antenna for Cloud Radar

Bing Yu*, Han Xia, Xiaoye Chen, Fei Yang, Fayu Wan, Zhenhua Chen, Yong Zhou, and Junxiang Ge

Abstract—A W-band dual-polarized Cassegrain antenna for cloud radar is proposed. The aperture diameter of the main reflector of the antenna is 50 cm. By using a modified Magic-T structure in the feed horn, the antenna is dual-polarized with high port isolation. The measured results show that the port isolation is 44.7 dB. The gains are 47.3 dB and 49.5 dB for the two ports at 94 GHz, respectively, and the efficiency of the antenna is better than 87%.

1. INTRODUCTION

Dual-polarized Cassegrain antennas at W-band have found extensive applications in millimeter cloud radar [1–3]. Millimeter cloud radar with dual-polarization capability is highly desirable for the current estimation of microphysical properties of cloud [4]. As we know, the polarization of the linear polarized incident wave will be rotated by the non-spherical cloud particle such as water-drop or ice, and in this case a dual-polarized Cassegrain antenna is deployed to receive the vertical and horizontal polarization components in the backscattering wave respectively. The ratio between the two polarization components, which is named linear depolarized ratio (L_{dr}), is an important parameter for the cloud radar to perform cloud particle inversion [5, 6]. High precision measurement for L_{dr} is necessary since the rotation of the polarization is usually very tiny, and thus high port isolation (> 40 dB) for the antenna at the same frequency is required [7]. However, the co-frequency interference will be a serious challenge to fulfill such high port isolation in W-band. Although a polarizer can be used to separate the two orthogonal waves by transmitting one and reflecting another one [8], the loss caused by the polarizer will be a serious issue in W-band. In [3], a 2×2 array square waveguide feeding structure is used in a W-band Cassegrain antenna, and in [9], an ortho-mode transducer with multi-feed is deployed in an X-band Cassegrain antenna, but their complex structure will increase the antenna cost and make it hard to assembly in W-band. In this paper, a novel dual-polarized Cassegrain antenna with a simple structure and high port isolation (> 44 dB) is proposed by using a modified Magic-T structure in the antenna feed. We will first state the design of the antenna feed and then validate it through the measure results of the proposed antenna.

2. ANTENNA DESIGN

For Cassegrain antenna, the port isolation feature is mainly determined by the antenna feed, which we will give a detailed description in the following section. As well known, the conventional Magic-T as shown in Fig. 1(a) is often used in microwave system with 4 ports (indexed by P_1, P_2, P_3, P_4), and for an ideal lossless Magic-T, if port P_1 is used as input port, port P_2 will be isolated, and vice

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* Corresponding author: Bing Yu (yubing@nuist.edu.cn).
The authors are with the Collaborative Innovation Center on Forecast and Evaluation of Meteorological Disasters, Nanjing University of Information Science & Technology, China.

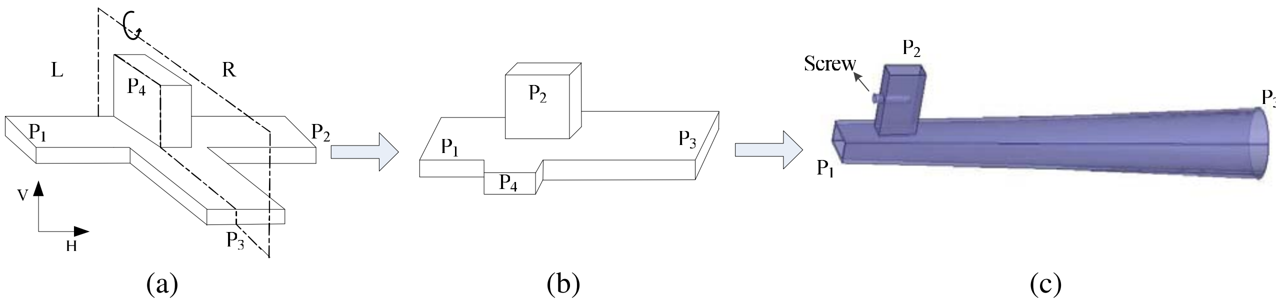


Figure 1. The evolution of the antenna feed structure with (a) conventional Magic-T, (b) modified Magic-T and (c) antenna feed.

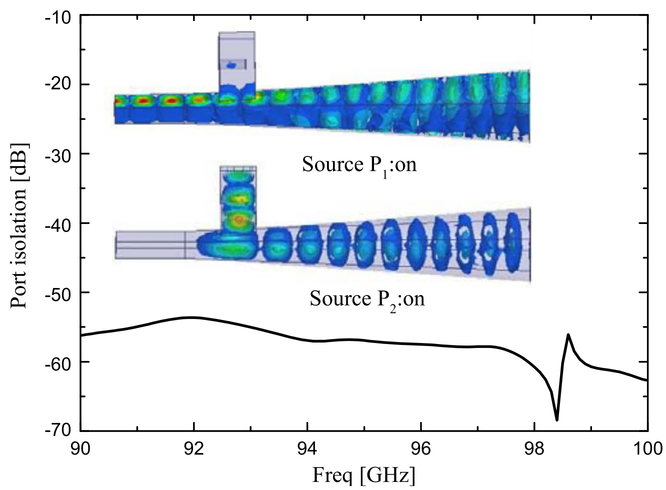


Figure 2. Simulated port isolation of the antenna feed.

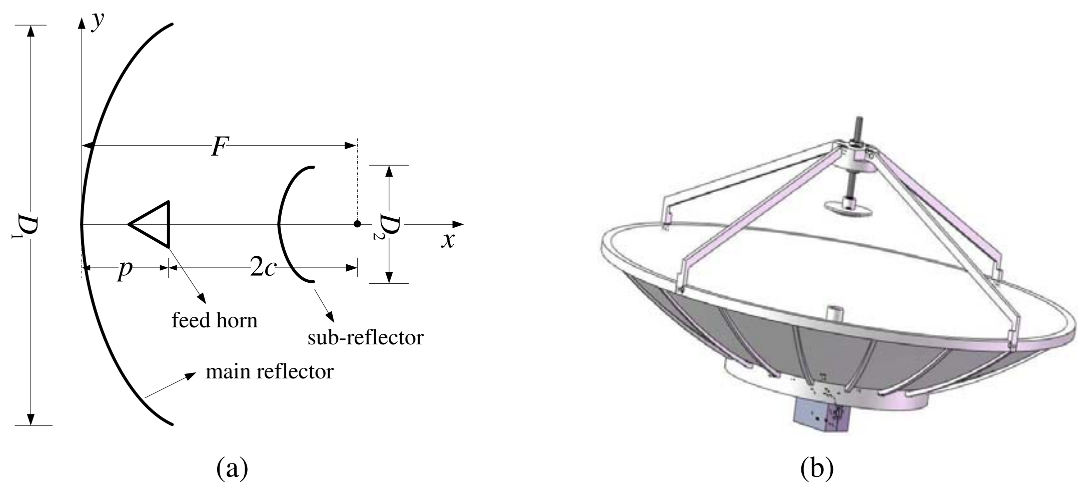


Figure 3. Cassegrain antenna in which (a) cross section and (b) 3D model.

versa. In this paper, the port isolation feature of Magic-T is deployed into the antenna feed design. Firstly, the conventional Magic-T is modified by rotating the right part of the conventional Magic-T 90° counterclockwise as shown in Fig. 1(b). Secondly, for antenna to be used in cloud radar, the aperture size of P_3 should be enlarged to receive different linear polarization waves, and P_4 is unused. The final antenna feed structure is shown in Fig. 1(c). From this figure, it can be seen that a rectangular-circular waveguide transformer is used to realize the resistance match for P_1 to P_3, and a metal screw is deployed to realize the resistance matching of P_2. P_1 and P_2 are both ended with WR-10 waveguide. Due to the requirement of cloud radar, an elliptical aperture is adopted in P_3 to obtain a similar contour of the radiation patterns for E- and H-planes. The whole antenna feed has a symmetric structure in the vertical direction which is benefitial for antenna fabrication and assembly. As shown in Fig. 2, the simulated field distributions for source P_1 on and source P_2 on is performed by the high frequency structure simulator (HFSS) respectively. From this figure, it can be seen that a high isolation between the two ports can be realized by using the modified Magic-T structure, and the isolation is better than -50 dB from 90 GHz to 100 GHz. The Cassegrain antenna diagram is shown in Fig. 3(a) designed by a standard procedure [10], where D_1 is the aperture diameter of the main reflector, D_2 the aperture diameter of the sub-reflector, F the focal length of the main reflector, p the length between the vertex of the main reflector and the phase center of the antenna feed, and c the focal length of the sub-reflector. The main reflector is formed by a rotational paraboloid which is written as

$$y^2 + z^2 = 4Fx \tag{1}$$

The set of F/D_1 is equal to 0.33, and the sub-reflector is formed by a rotational hyperboloid which is written as

$$\frac{(x-c-p)^2}{a^2} - \frac{y^2}{b^2} = 1 \tag{2}$$

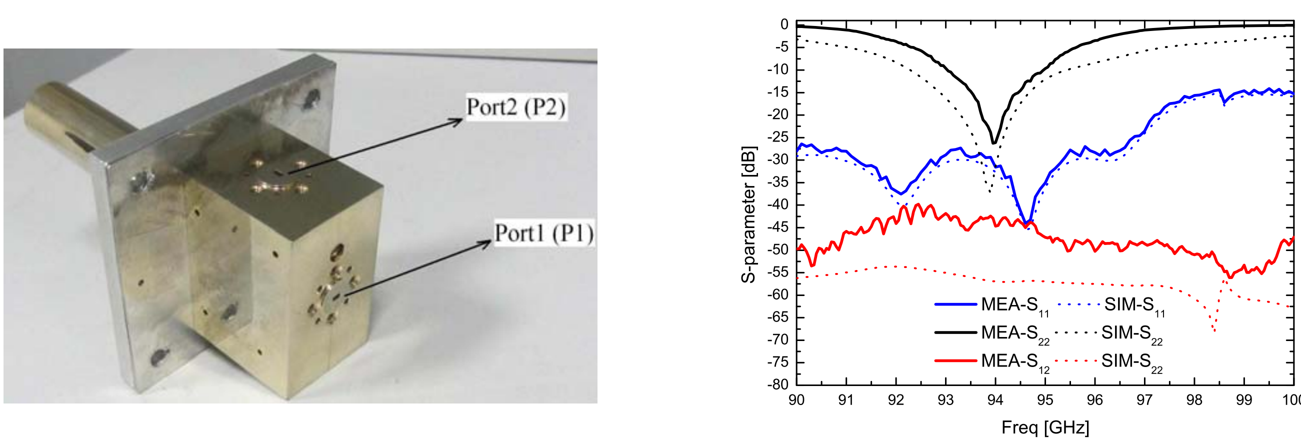
where $a = 15$ cm, $b = 20$ cm. In order to minimize the blockage of the sub reflector, the ratio of D_2/D_1 is set < 0.07 with

$$D_2 = \sqrt{k_w \lambda F} \tag{3}$$

where k_w is the beam width constant of the feed and λ the wavelength. For optimizing antenna gain. A -10 dB edge taper is used, which corresponds to a feed pattern with a cosine to the power, q equal to 68.6 [11].

3. RESULTS AND DISCUSSION

The S-parameter of the feed horn as shown in Fig. 4(a) is measured by the Agilent PNA-X network analyzer N5244A and millimeter wave VNA extender (75–110 GHz). The measured and simulated results of the S-parameter are shown in Fig. 4(b). From this figure, it is seen that the measured isolation (S_{12}) is better than 44.7 dB at 94 GHz and also shows a good agreement between the simulation and measurement results. The impendence bandwidth of P_2 (S_{22}) is narrow compared with P_1 since the impendence matching of P_2 is achieved by using a metal screw which can be equivalent to a series



(a) (b)

Figure 4. Antenna feed (a) photograph of the fabricated feed and (b) measured S-parameter.

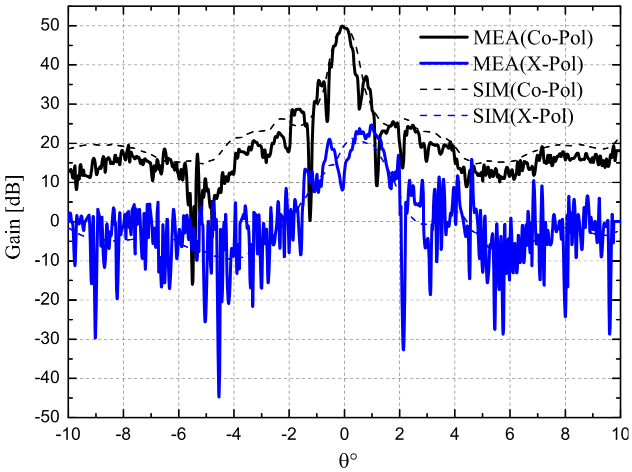


Figure 5. Radiation pattern of P_1.

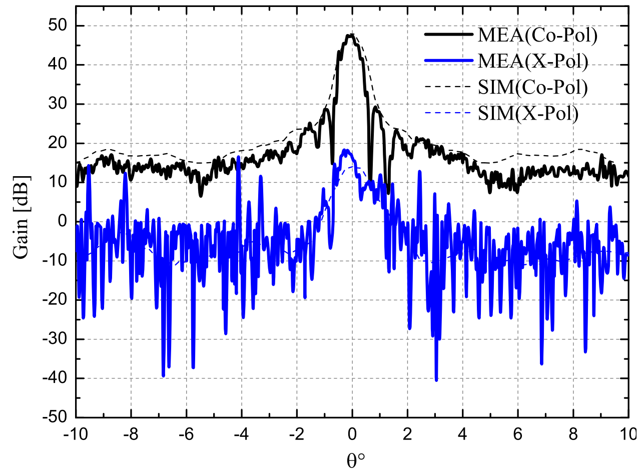


Figure 6. Radiation pattern of P_2.

Table 1. Measure results at 94 GHz.

Ports	Gain [dB]	Side-lobe level [dB]	$2\theta_{0.5}$[°]	XPD [dB]	Efficiency
P_1	49.5	−17.3	0.434°	31	91.9%
P_2	47.3	−14.4	0.38°	37	87.9%

capacitance and inductance circuit. The proposed Cassegrain antenna is measured by using a compact range and the Co-pol and X-pol far-field radiation patterns of the proposed Cassegrain antenna, and simulation results are shown in Fig. 5 and Fig. 6 for P_1 and P_2, respectively. From the two figures, it can be seen that the gain of P_1 is bigger than P_2 mainly for the resistance mismatch of P_2, and the loss caused by the metal screw also contributes to the gain decline of P_2. The measured results of gain, side-lobe level, half power beam width ($2\theta_{0.5}$), cross polarization discrimination (XPD) and efficiency for the two ports are shown in Table 1.

4. CONCLUSION

In this paper, a novel dual-polarization Cassegrain antenna for cloud radar is proposed. By introducing a modified Magic-T structure in the antenna feed, the port isolation is better than 44.7 dB at 94 GHz, and the efficiency of the antenna is better than 87%. Thanks to the modified Magic-T structure used in antenna feed, the antenna is easy to be fabricated and assembled.

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