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A 50 dBi Dual-reflector E-Band Antenna for 5G Backhaulings with Beam Steering Function

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Summary

An ultra-high-gain dual-reflector antenna with beam steering for 5G backhaul is proposed, where the feed is based on a mechanically reconfigurable gap-waveguide configuration that enables the movement of the feed while keeping the interface with the node (or radio) stationary. The antenna has been prototyped with a measured reflection coefficients below -10 dB for both horizontal and vertical polarization over 71-86 GHz, and the reflection coefficients are almost independent of the position of the feed horn. The measured radiation patterns agree well with the simulated ones, the overall antenna gain is approximately 50 dBi in the E band, and the beam steering within ± 2.5 deg is achieved.

1 Introduction

5G and beyond 5G wireless communication systems will provide ultra-fast data transfer up to 10 Gbps with an ultralow latency of 1 ms, which can be realized only inevitably with the support of millimeter wave (mmWave) systems. Delivering high data rate in mmWave backhauling (point-to-point) systems over long distances is a big challenge due to the severe path loss and other limitations. Since it is not economically viable to deploy backhaul systems with station towers within every hundred meters, ultra-high gain ($\geq$ 50 dBi) antennas operating at mmWave regime are the core to implement 5G mmWave backhauling systems sustainably with a long-distance coverage [1]. Pencil-beam antennas for point-to-point links are typically reflector based, due to their high gain, good efficiency, low cost, and low sidelobe characteristic. However, the ultra-high antenna gain means ultra-narrow beamwidth (50 dBi gain requires a narrow 3-dB beamwidth of about 0.6°), where vibrations and wind load on the antenna may cause the antenna beam swing and result in disruption of the link. Therefore, the beam tracking becomes a critical requirement for mmWave backhauling ultra-high-gain antennas. Beam steering of reflector antennas can be achieved by changing the configuration of the antenna system. Considering the weight of the reflector, it is easier to achieve off-focus feeding by moving the feed antenna [2] to realize the beam steering. When the above solution is adopted, the interface with the rest of the system (the radio) should be fixed to have a reliable connection. However, there must exist gaps between the movable feed horn and the fixed interface ports for its smooth movability. At mmWave frequencies, even a very small gap can cause very serious energy leakage and undesirable resonances, which seriously affects the performance of the antenna. To solve this problem, a GW-based mechanical motion solution is proposed in this paper.

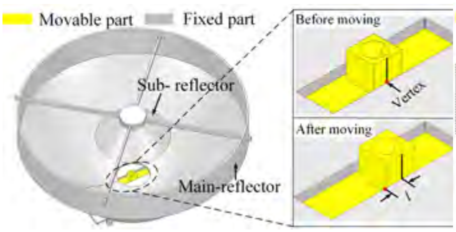

Figure 1. Geometry of the antenna.

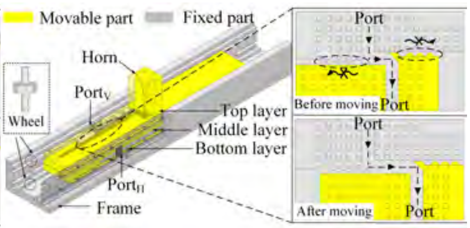

Figure 2. Geometry of the movable feed.

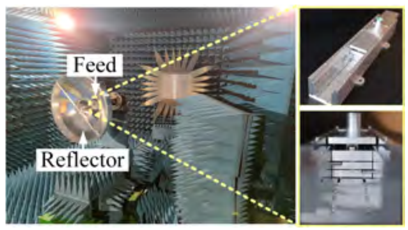

Figure 3. Prototype.

2 Antenna Design

The antenna structure is shown in Fig. 1, which consists of a dual-reflector and a movable Gap waveguide feed. The main reflector has a circular hole at the vertex, where a feed is allocated and can be moved in the hole. When the feed is at the vertex, the phase center of the feed is at the focus of the sub-reflector in order to have maximum antenna efficiency and low sidelobes. When the feed is moved away from the vertex, referred to as the off-focus feeding, the main beam of the whole reflector antenna will be steered to an angle away from the boresight.

The geometry of the movable GW feed is given in Fig. 2, where the surrounding metal plate (grey) is fixed to the reflector and the two ports located on either side are kept fixed to the radio. Its interior consists of three movable layers (yellow), where the middle and bottom layers are the feeding network and the top layer is the feed horn. To ensure smooth movement, there are 80 μm gaps between the top, bottom, left and right sides between the movable block and the fixed block, and pins are added at all walls to form PEC-AMC parallel plate structure to prevent energy leakage and undesired resonance. The black dashed line in the Fig. 2 indicates the direction of electromagnetic (EM) wave transmission. As the moving block is moved, the path of EM wave propagation will be altered.

3 Experimental results

The proposed antenna is fabricated as shown in Fig. 3, the simulation S-parameters for the feed at the vertex and the measured S-parameters for every 10 mm movement of the feed are presented in Fig. 4 (a). It shows that the reflection coefficient is better than -10 dB at both ports over 71–86 GHz, and the measured S-parameters at both ports agree with the simulation results, indicating that the movement of the feed has almost no effect on the S-parameters. The radiation characteristics of the feed are measured at Chalmers new mmWave lab with the far-field range setup. The simulated and measured radiation patterns of the feed at 80 GHz in the E- and H-planes are shown in Fig. 4 (b), and the feed gain is given in Fig. 4 (c). The simulated and measured results agree with each other very well, indicating that the gap introduced for waveguide movement does not lead to energy leakage due to our PEC-AMC structure. The feed achieves dual-polar high performance over 71–86 GHz. Figs. 4 (d) and 4 (e) give the measured radiation patterns and gain of the whole antenna, measured by the compact range test at Chalmers new lab, with about 50 dBi gain over the entire frequency band and the sidelobes nearly satisfied with ETSI class 3. Finally, Fig. 4 (f) shows the radiation patterns of the whole antenna when the feed is moved, where the beam steering is successfully realized while the system interface remains stationary.

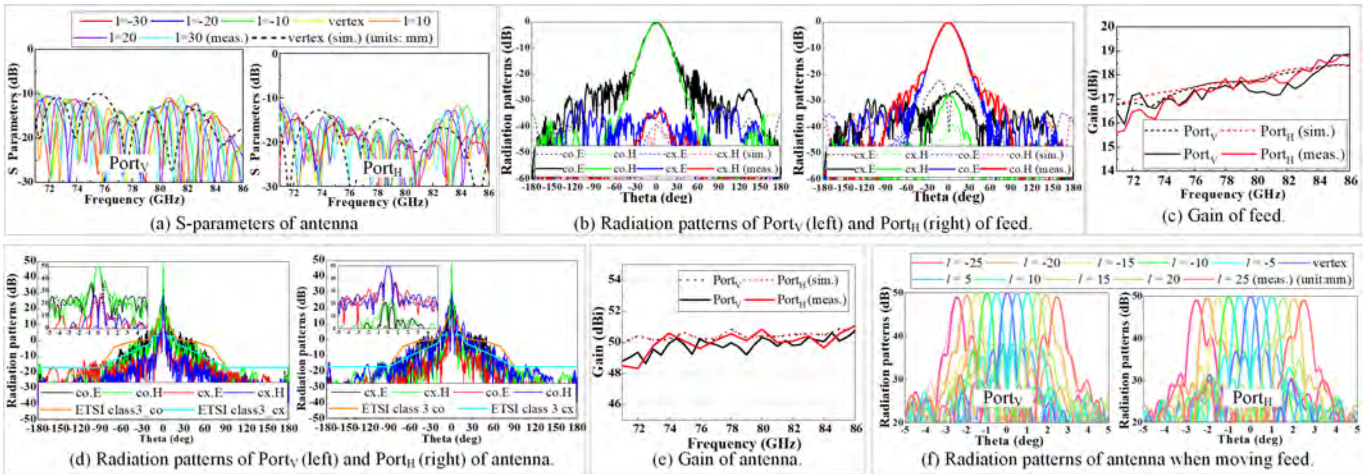

Figure 4. Results of simulation and measurement.

4 Conclusion

The antenna proposed in this paper can provide ultra-high gain of about 50 dBi with beam steering within $\pm$ 2.5 deg and sidelobe envelope below ETSI class 3. The mechanically movable feed in the system allows the feed to move while keeping the interface with the radio stationary through the use of a quasi-PEC-AMC structure. Measurements of the prototype have verified its high performance. The proposed antenna is aiming to be used in 5G mmWave backhauling systems.

5 Acknowledgements

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