A Broad Beam-Width Dual-Polarization Microstrip Dipole Antenna for 5G MIMO Application

You-wei LIU¹,*, Xiong-jie JIN¹, Xiao YU² and Hou-jun SUN¹

¹Beijing Key Laboratory of Millimeter Wave and Terahertz Techniques, Beijing Institute of Technology, Beijing 100081 China
²Department of Engineering Mechanics, Tsinghua University, Beijing 100084, China

*Corresponding author

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Abstract. A novel S-band antenna is proposed in this paper. The antenna consists of two layers of radiant dipole. The unit is capable of realizing broad beam-width of 144° in E-plane with isolation better than -35dB between two ports. The circular polarization can be achieved by exciting two ports with equal amplitude and 90° phase difference. Moreover, the axial ratio is less than 2dB in the antenna operating frequency band. At last, a triangular grid array with 64 elements is designed. The simulated results show that the designed array can meet the requirements of large scanning angle. It can be applied for the fifth generation mobile communications (5G) Multiple-Input Multiple-Output (MIMO) base station.

Introduction

The 3D MIMO with wide beam antenna meet the need of the great communication capacity and spectral efficiency in 5G.

Microstrip antenna has the advantages of easy fabrication, good structural stability, low cost, et.al. It has been pointed out in the papers [2-4] that the 3 dB beam width of the conventional microstrip antenna is about 100 °, and the beam width is not wide enough to meet the requirement of array beamforming. Compared with conventional microstrip antennas, dipole antennas have the advantage of wider beam, but their structural strength is poor. In another paper [5] a single cross junction microstrip dipole antenna operating at Ku-band is designed. The beam width is above 126°, but the port isolation is only -18dB.

Combining the advantages of microstrip antenna and dipole antenna, a novel double layers microstrip antenna element is designed. The antenna element is a vertical and horizontal dual polarized antenna operating at S-band. In accordance with actual requirements, the unit can also be used as a circularly polarized antenna with two ports operating at the same time. In this antenna unit, the parabolic curve is used as the main radiation part to realize wide beam. The antenna has wide beam and ideal bandwidth. On the basis of this antenna element, a triangular grid plane array is formed, weighted to the horizontal dimension and the vertical dimension, respectively. The results show that the synthesized beam can achieve better coverage and scanning in the planar array.

Antenna Design

The center frequency of the microstrip dipole antenna is 3.5GHz. The structure of this antenna, shown in Figure 1, is divided into 4 layers. The first and third layers are Taconic RF-35, and the thicknesses are 1.92mm, 1.64mm, respectively. In order to broaden the bandwidth and increase the isolation between the two ports. The height of the air (layer 2) is 1.55mm The fourth layer is made of Taconic TLY material with a thickness of 12mm.
The antenna is fed by coaxial lines and then transmit energy to the radiation patches via metal plates and metal columns. The radiation patch adopts a gradient structure, and the contour equation is parabolic, the curve is equation (1). The horizontal and vertical radiation patches are located on the lower surface of the first dielectric layer and the upper surface of the second layer medium, as shown above.

\[ y = 0.456 \times x^2 + 3.7 \] (1)

**Result and Discussion**

The antenna structure has 4 layers, and the air structure is between the first and the third layers. The height of the air rack has great influence on the antenna performance, and is one of the key parameters. The above antenna unit is simulated by ANSYS High Frequency Structure Simulator (HFSS) 18. The simulation results are as follows:

**Return Loss and Isolation**

From Figure 2, we can obtain that the bandwidth of the port 1 is narrower than the port 2, but the return loss bandwidth of the port 1 better than -10dB is still 14%. That is to say it has excellent standing wave characteristics.

In the simulation process, it is found that the air height is also helpful to improve the isolation of the ports. Moreover, the height of the air rack (parameter Hair) has a great influence on the standing wave and the isolation of the ports. The influence of the height of the air layer on the return loss is shown in Figure 3. It can be seen that the air layer (layer 2) parameter Hair has a great influence on the Port 2’s return loss. As we can see from Figure 4, the isolation of the two ports is also sensitive to the parameter Hair. We can conclude that the height of the air rack plays a role in improving the isolation of the ports.
Radiation Pattern and Cross-Polarization

Analysis of the horizontal port (port1): At the center frequency (3.5GHz) 3dB beam width on E-plane is 144°, cross polarization is 17.8 dB. The maximum realized gain is 5.8 dB among theta=0° and phi=0°.

Analysis of the vertical port (port2): At the center frequency (3.5GHz) 3dB beam width on H-plane is 129°, cross polarization is 21.6 dB. The maximum realized gain is 6.51 dB among theta=0° and phi=0°.

According to the above analysis, the antenna bandwidth is 14%. The beam width on E-plane is up to 144° in the center frequency when the port1 is excited, while H-plane is 129° when the port2 is excited. In a word, this kind of antenna can be well applied to the 5G MIMO array because of its wide beam characteristics. On the other hand, if the two feed ports are excited at the same time and the phase difference of the ports are 90°, circular polarization can be achieved. The axial ratio characteristics are as follows. It can be seen from Figure 6, in the operating frequency range, the axial ratio is less than 2dB at the direction (0°, 0°). The antenna can achieve great circular polarization.
Analysis of Antenna Array

We designed an antenna array using the antenna unit described in the previous section. The array beam characteristics were analyzed using the software named Matlab.

In order to achieve better low sidelobe level, the array uses triangular grid arrangement, as shown in Figure 7. As for the horizontal (x) direction, the array spacing is 0.7 $\lambda$, and the Taylor distribution is adopted to depress the width of the main lobe by raising the sidelobe level. In the vertical (y) direction, the element spacing is also 0.7 $\lambda$. Through the MATLAB optimization toolbox, a sidelobe factor was designed to narrow the main valve width, and we obtained a very narrow pen shaped beam.
Figure 8. Simulated scanning angle (0°,0°) radiation pattern (a) horizon plane (b) vertical plane (c) 3D.

Figure 8. shows that the realized gain of the pencil beam reaches 25.3 dBi without scanning. The half-power beam width (HPBW) is 9.4° on the horizon plane while the HPBW is 10.4° on the vertical plane. The side-lobe level (SLL) is -12.2 dB on the horizon plane and the SLL is -11.5 dB on the vertical plane.

When the horizontal scanning angle is 60°, the realized gain is 18.6 dBi and the HPBW is 18° on the horizon plane. When the vertical scanning angle is 30°, the realized gain is 24.5 dBi and the HPBW is 12°. We can obtain this information easily from the Figure 9 and Figure 10.

Figure 9. Radiation pattern on horizon plane scanning (60°,0°).

Figure 10. Radiation pattern on vertical plane when scanning (0°,30°).
Summary
A wide beam dual line polarized microstrip dipole antenna operating at S-band is proposed in this paper. The antenna adopts double layers microstrip dipole radiation. The antenna element can achieve a wide beam of 144° and port isolation better than -35dB by adjusting the parameters properly such as the height of the air layer. The simulated results show that this antenna is suitable for the application of the low frequency band in the fifth generation mobile communication system (5G) and radar system.

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References