Analysis of OAM Mode Purity in Phased Array Antenna

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Abstract: In this paper, the orbital angular momentum of different modes in electric field is decomposed, and the definition of purity of OAM mode in OAM antenna are proposed. Based on the purity theory, the purity of circular array is derived. And the effects of different parameters on the purity are analyzed. An intuitive and quantifiable dimension for comparing the OAM performance in phased array antenna is provided in this paper.

Keywords: Orbital Angular Momentam (OAM); Phased Array Antenna; Mode Purity; Uniform Circular Array (UCA)

Introduction

OAM based on phased array antenna structure Antenna can obtain infinite transmission energy by using orbital angular momentum electromagnetic vortex multiplexing force. This new type of technology provides the possibility to solve the congestion problem in radio frequency band[1]. In recent years, there have been more and more reports about the research and analysis of OAM antenna array, in Th< the method of OAM generation using rectangular array and hexagonal array was analyzed for the first time[2], and in the same year, the phase mode theory of circular array[3] was also proposed for the first time, providing more research ideas and new directions for orbital angular momentum antenna array.

When using phased array antenna for OAM and communication, mode purity is an important dimension to measure reliable information transmission. In recent years, many people have measured the mode purity of vortex electromagnetic wave in engineering. But there has been a lack of detailed theoretical derivation and proof. This paper constructs a set of OAM and mode purity calculation methods through theoretical derivation and numerical simulation, which introduces a new dimension to the measurement of electromagnetic vortex antenna.

1. OAM and mode decomposition

1.1 OAM, circular array decomposition

OAM When applied to electromagnetic waves, add a phase rotation factor to normal electromagnetic waves, and then the wave front of the electromagnetic waves will longer a planar structure, but rotates around the beam propagation direction, presenting a spiral phase structure. Different, OAM, Modality, the spatial structures of the state vortex beams are different and orthogonal to each other, which can carry different signals[6].

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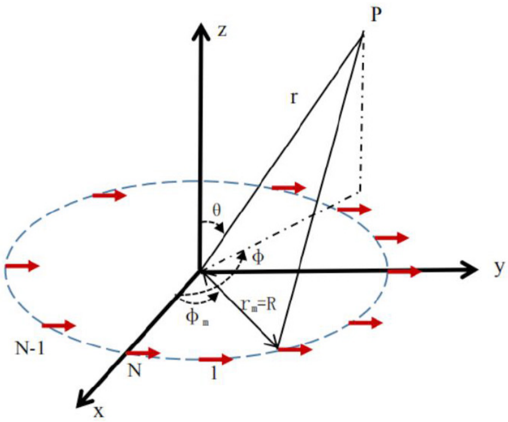

Figure 1. Uniform circular array antenna with N units.

In the circular array shown in Figures 1 and m cells are located in the spherical coordinate system. and the current excited on them is where is an integer and represents the number of modes excited by the antenna. The vector magnetic potential can be expanded into Fourier series[7].

1.2 Mode generation conditions

It can be seen from Figure 2 that the amplitude of the excited OAM mode vector magnetic bit can only maintain a higher amplitude at a relatively small beam angle, i.e. as the angle increases, the interference of different modes increases and the purity deteriorates[8].

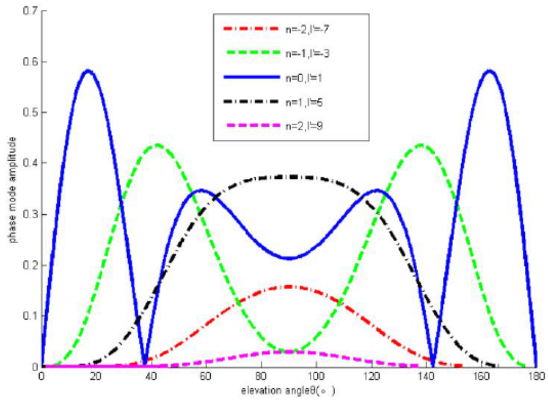

Figure 2. When feed mode l=1, the actual intensity distribution of magnetic vector potential in different modes.

2. Mode purity of circular arrays

2.1 Definition

OAM and mode purity are defined as the ratio of the energy of a mode wave to the energy of the whole OAM and beam energy[9], the energy density of the field radiated by the antenna in a certain direction is proportional to the square of the electric field, the electric field of the far field of the antenna is proportional to its vector magnetic potential, and the mode purity can be defined as the ratio of the mode square of the vector magnetic potential of a certain mode to the sum of the mode squares of all modes under a specific angle.

The purity of the comparison mode is mainly carried out from two aspects: one is to see whether a certain purity can be maintained at a larger beam angle, and the other is to see whether a higher purity can be maintained at a certain beam angle (generally taking 38°).

2.2 Analysis of parameters affecting model purity

Figure 3-5 show the OAM circular array mode purity versus spatial angle θ under different parameter changes. Figure 3 is the mode purity of circular arrays with different radii. As can be seen from the figure, the purity is inversely proportional to the radius of the circular array. The smaller the radius, the higher the purity of the antenna can be maintained at a larger beam angle. The larger the radius, the faster the purity fades, and the more the change period in the beam angle.

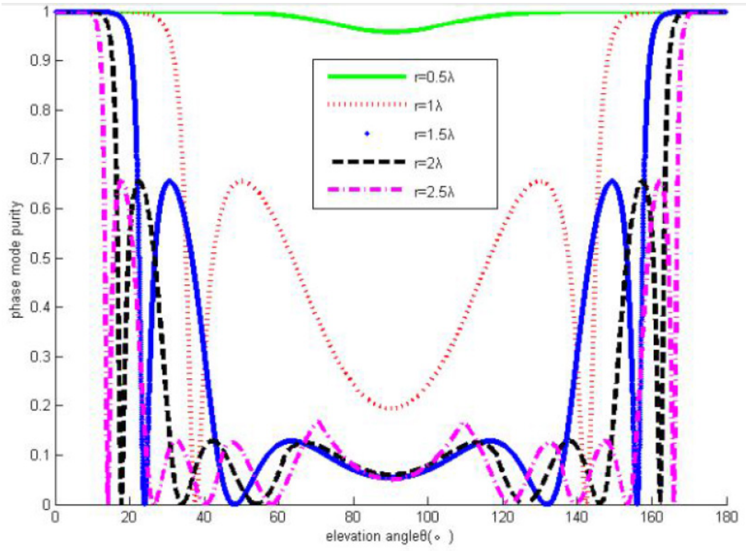

Figure 3. 3Mode purity with different radius (l=1, N=8).

Figure 4 is the mode purity of circular arrays with different number of elements. As can be seen from the figure, the purity of circular array mode and the number of cells N proportional, the more the number of elements, the more the antenna can maintain high purity at a larger beam angle; The smaller the number of cells, the purity is at the beam angle, the faster the decline.

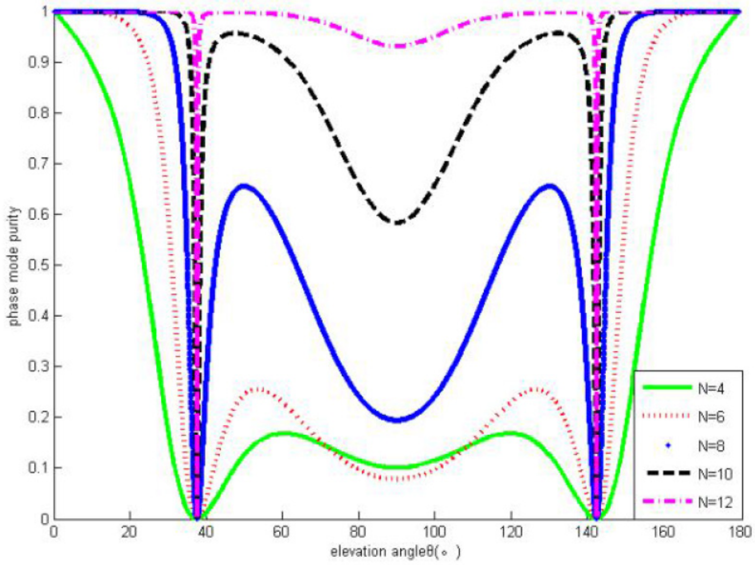

Figure 4. 4Mode purity with different N (l=1, R=1 λ).

Figure 5 is the purity of different excitation modes. As can be seen from the figure, the mode purity of the circular array is inversely proportional to the value of the feeding mode. The closer the feeding mode is to zero, the higher the antenna can maintain high purity at the beam angle. The further away the feed mode is from zero, the faster the antenna purity declines at the beam angle, and the further away the singularity is from the propagation radius.

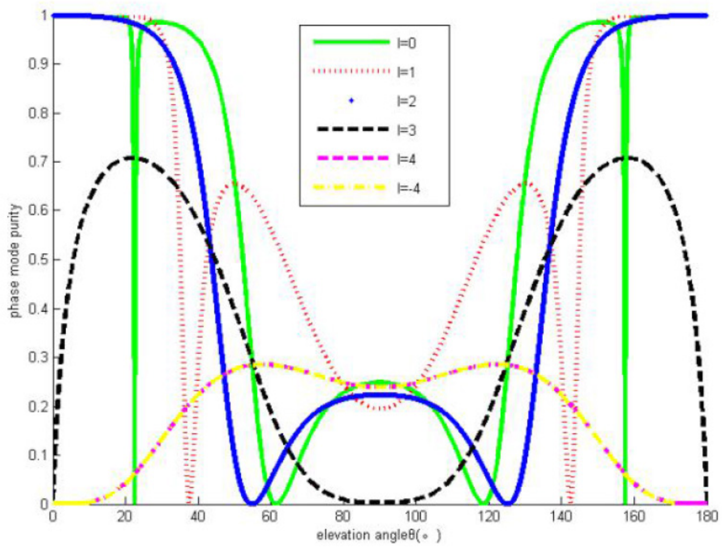

Figure 5. 5Mode purity with different *l* (N=8, R=1 λ).

3. Conclusion

In this paper, the definition and formula of OAM and mode purity are proposed. The vector magnetic potential of the space field of OAM and circular array is decomposed by Fourier expansion series of the vector magnetic potential of the circular array. The mode purity of the OAM field generated by the circular array is analyzed, and the influence of different parameters of the circular array on the purity is comprehensively analyzed. The results show that smaller radius and more elements in the circular array can make OAM array produce vortex electromagnetic wave with better purity in the beam angle. At the same time, the smaller the mode value of the feed mode (the closer the value is to zero), the better the purity of its main mode in the beam angle, the slower the fading.

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