A Design of High Gain Wideband Circular Polarization Antenna Based on All-Metal Vivaldi Antenna

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Abstract. This paper designs a broadband circularly polarized antenna covering the 25 GHz to 31 GHz band. The Vivaldi antenna is used as the basic structure to generate broadband electromagnetic waves; circular polarization is achieved by feeding through a circularly polarized bridge; a metal choke ring is used at the bottom to ensure the low side lobes of the antenna. The antenna consists of four basic Vivaldi antennas, a metal choke ring, a grounded substrate, and a feed network. The results show that the antenna covers the entire frequency band when the axial ratio is lower than 3 dB, and the impedance matching is better. The use of a choke ring structure ensures that the antenna electromagnetic waves are radiated upward, resulting in higher gain and lower side lobes. The highest gain in the included frequency band is 11.4 dB, and the simulation result is good. The antenna has high gain and low sidelobe characteristics.

1. Introduction

With the development of modern electromagnetics, circular polarization (cp) antenna is one of the most widely used antennas. Due to its orthogonality of rotation, the circular polarization wave incident on the symmetrical target is a rotational reversal, so it has the characteristics of high reception efficiency and effective suppression of rain and fog interference, and has been widely used in the fields of mobile communication, electronic interference and satellite positioning system. With the development of antenna technology, there are many circular polarized antennas, such as spiral antenna [1] and [2], gap antenna [3] and [9], and ring antenna [4] and [10].

The Vivaldi antenna is an exponentially graded slot line antenna. At different frequencies, different parts of the slot line transmit or receive electromagnetic waves. Therefore, the Vivaldi antenna has the characteristics of end firing, wide frequency band, high gain, etc., and it has a low profile, light weight, It has the advantages of easy processing and so on, and has a wide range of applications in communication systems [5]. In the application of literature [6] and [7], two Vivaldi antennas are placed across each other, and the corresponding feed network is used for feeding, to generate circularly polarized electromagnetic waves. Literature [8] designed a 2×2 small rotationally symmetric circular polarization array, which has good circular polarization performance in the frequency range of 7GHz to 13GHz.

The paper designs an antenna which generates circular polarized electromagnetic wave from 25GHz to 31GHz frequency band. It adopts 2×2 all-metal antenna unit and uses metal choke ring at the bottom of the antenna unit to make the antenna have lower sidelobe and higher gain.
2. Design of Antenna

2.1. Antenna element structure
The basic structure of the antenna is shown in Figure 1 (single Vivaldi antenna). In order to achieve the broadband characteristics of the antenna, the Vivaldi antenna with ultra-wideband operating characteristics is used as the basic array of circular polarization. Gradient groove and resonant cavity constitute radiator structure, and the feed system is composed of a coaxial connector and an impedance transformation belt. In the radiation unit part, the square structure loaded at the end of the slot line is the resonant cavity of the antenna, so that the slot line can realize short-circuit effect in a wider frequency band. The antenna uses an exponential curve, and the expression is \( y = \pm (C_1 e^{Rx} + C_2) \). Antenna parameters are: \( L1 = 6.3 \) mm, \( L2 = 0.6 \) mm, \( L3 = 0.4 \) mm, \( M = 2 \) mm, \( M1 = 5.2 \) mm, \( M3 = 0.8 \) mm, \( M4 = 0.8 \) mm, \( M5 = 0.2 \) mm.

Where, \( C1 \) and \( C2 \) are constants, and \( R \) is the gradient factor of the exponential function, which determines the beam width of the antenna. Different slot widths correspond to corresponding working frequency points. The widest slot line corresponds to the lowest frequency of the antenna, while the narrowest slot line corresponds to the highest frequency of the antenna. In the feeder system, the electromagnetic wave energy on the feeder can be better coupled to the radiator by coupling the feeder probe with the slot gap to keep the open state in a larger frequency range.

![Figure 1. Vivaldi antenna unit structure and parameters (a) Vivaldi antenna unit structure (b) VSWR.](image)

2.2. Design of circular polarization antenna
A circularly polarized electromagnetic wave can be decomposed into two orthogonal linearly polarized electromagnetic waves in space and time. Therefore, the basic principle to realize circular polarization is to produce two orthogonal linearly polarized electric field components in space with the same amplitude and phase difference of 90°. So this article uses the literature [8] design methods, the method uses multiple linear polarization units rotating circular polarized array order disposal method, four Vivaldi antenna units cruciform rotational symmetry structure, each port feed a difference of 90° respectively, respectively 0° and 90°, 180°, 270°, as shown in figure 2(a) (3D full size chart). For the two polarized electromagnetic waves, each antenna is rotated orthogonally, and the different feed phases provide the phase delay needed to generate circular polarization. The feed network is shown in Figure 2(b).
At the same time, a metal choke ring with a height of 6mm, a radius of 6.7mm and a thickness of 0.2mm is designed. The choke ring and the antenna array form a resonant structure of the cavity, which can limit the energy in the cavity and reduce the backward radiation of the antenna. Therefore, the antenna has a lower sidelobe and a higher gain.

3. Analysis of Simulation Results

3.1. VSWR and Axial Ratio and Gain Performance

As shown in Figure 3(a), the voltage standing wave ratio of the four ports in the whole 25GHz to 31GHz band is less than 2-dB. As shown in Figure 3(b), the axial ratio in the whole frequency band is below 1.01, and the antenna can achieve circular polarization. The antenna gain is shown in Figure 3(c). The highest gain of the antenna in the whole frequency band is 11.4-dB.
Figure 3. The antenna parameters (a) VSWR (b) Axial Ratio (c)Antenna gian.

3.2 Radiation performance

Figure 4 shows the normalized radiation diagram simulated on the XOZ and YOZ plane under the conditions of 33 GHz, 34 GHz and 35 GHz, respectively. As can be seen from the radiation diagram, the antenna has a lower sidelobe.
4. Conclusion
In this paper, a novel wideband circular polarization antenna based on Vivaldi antenna structure is designed. The four Vivaldi antenna elements are in a positive intersection arrangement, and the feed network with equal amplitude and phase difference of 90° is used to feed the antenna, so as to ensure that the antenna produces circular polarized electromagnetic waves. The antenna has good axial ratio and radiation performance from 25 GHz to 31 GHz band, and the side lobe is low. Based on the above advantages, the antenna has a wide application prospect in wireless communication.

Acknowledgments
This research was partially supported by Major Project of Provincial Natural Science Research of University of Anhui Province of China (Grant No. 61701003 and No. 61722101).

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