Design of Wideband Dual-Circularly Polarized Endfire Antenna Array on Gap Waveguide

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***Abstract*—A wideband dual-circularly polarized (CP) linear antenna array is presented in this paper. Firstly, a dual-CP endfire antenna based on septum polarizer is designed as the element for the array. Secondly, the feeding network is realized by ridge gap waveguide. Then a 1×8 linear antenna array is built up by the elements. The proposed array antenna achieves wide impedance bandwidth of 41.4% with the reflection coefficient below -10 dB, the isolation between ports greater than 15 dB, and a wide 3-dB axial ratio (AR) bandwidth of 41.1%.**

***Index Terms*—antenna array, dual-circularly polarized, endfire, gap waveguide.**

I. INTRODUCTION

In recent years, millimeter-wave (MMW) endfire antennas have a wide range of applications in short distance communication, such as mobile communications and indoor communications [1], [2]. Among these, CP endfire antennas become more attractive due to its advantages of lower multipath interferences, better mobility, and lower polarization mismatch between the transmitter and the receiver [3], [4]. Many CP endfire antennas based on conventional waveguide, such as the antipodal tapered slot antenna (ATSA) and the antipodal curved tapered slot antenna (ACTSA), exhibit advantages of low loss and low-profile [5], [6]. An ACTSA was employed to form antenna array fed by substrate integrated waveguide (SIW) network [7]. However, SIW brings dielectric loss in MMW band.

Gap waveguide is a new type of transmission line with excellent characteristics. It has been applied widely due to its advantages of low losses, easy assemble and wide bandwidth, especially at high frequency such as MMW band. A lot of planar slot arrays based on gap waveguide were proposed at MMW band [8-10]. To the best of our knowledge, endfire antenna on gap waveguide has been reported rarely. It is also a challenge to design a dual-CP antenna with wide bandwidth.

In this paper, a wideband dual-CP endfire antenna array on gap waveguide is proposed. A dual-CP endfire antenna based on septum polarizer is adopted as the element for the proposed array. The array consists of 1×8 elements with a gap waveguide network. The simulated results show that the proposed antenna achieves wide bandwidth both for impedance matching and axial ratio. The design details and simulated results are presented in Section II and III, and Section IV gives the conclusion.

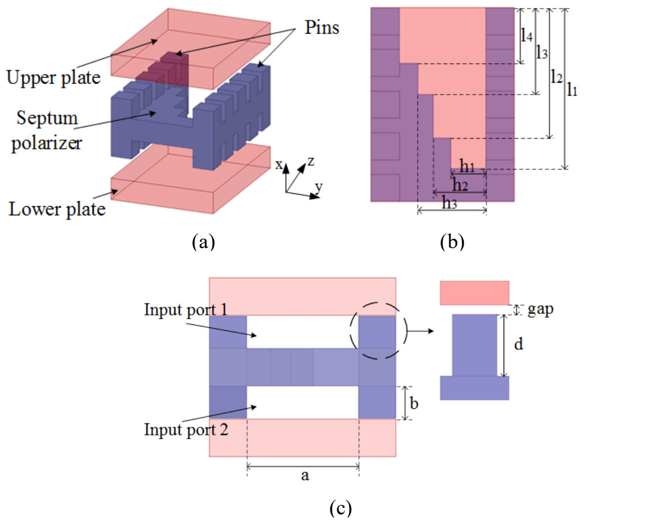


Fig. 1. Geometry of the proposed antenna element. (a) Perspective view. (b) Top view. (c) Side view.

TABLE I. PARAMETERS OF THE PROPOSED ANTENNA ELEMENT

Par.	a	b	l_1	l_2	l_3	l_4
Val.(mm)	6.0	1.8	9.55	7.4	4.39	2.27
Par.	h_1	h_2	h_3	d	gap	
Val.(mm)	2.43	1.21	1.08	1.75	0.05	

II. ANTENNA DESIGN

A. Element Design

The configuration of the proposed element is presented in Fig. 1, with its dimensions given in Table I. The structure is a two-layer groove gap waveguide, it is made of three parts: 1) a lower metal plate, 2) a metallic waveguide septum polarizer, and 3) an upper plate. By adopting the septum polarizer, the new orthogonal field component with a phase shift of 90° will be induced in the polarizer area when port 1 or port 2 is excited. Then circular polarization is produced with these two orthogonal modes and radiated from the open waveguide. When port 1 is excited, the antenna radiates a right-handed CP (RHCP) wave. In the opposite, it radiates a

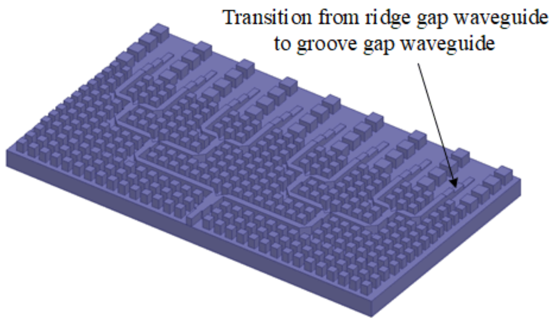


Fig. 2. Geometry of the feeding network.

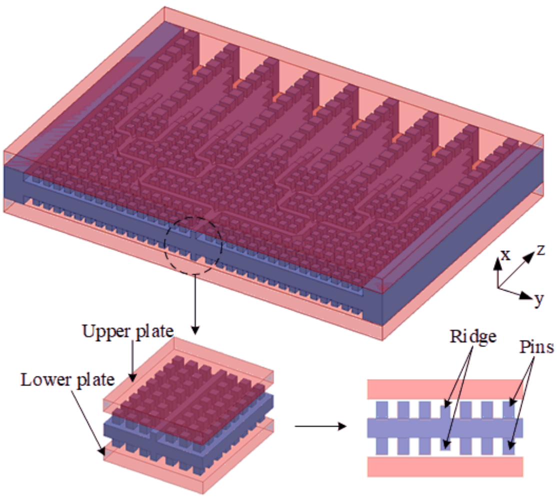


Fig. 3. Geometry of the array antenna.

left-handed CP (LHCP) wave when port 2 is excited. Two rows of metallic pins are utilized as the sidewall of the groove gap waveguide.

B. Feeding Network

The network consists of two parts which are power dividers based on ridge gap waveguide and the transitions from ridge gap waveguide to groove gap waveguide, with the same three layers as the radiation elements. Fig. 2 presents the configuration. Due to the stopband characteristics of EBG structure, the electromagnetic wave can only be propagated within air gap between the metal plates and the ridges. In order to fulfill the transition from ridge gap waveguide to groove gap waveguide, a 3-stepped ridges are used here. The parameters of feeding network are optimized in the simulation software HFSS.

C. Antenna Array

The array is made up of 1×8 elements fed with gap waveguide network shown in Fig. 3. There are three metal plates, and the middle one is with ridges and pins on it. Thus the proposed array antenna can be easily assembled. The total size of the array is 76 mm × 49.75 mm × 9.6 mm.

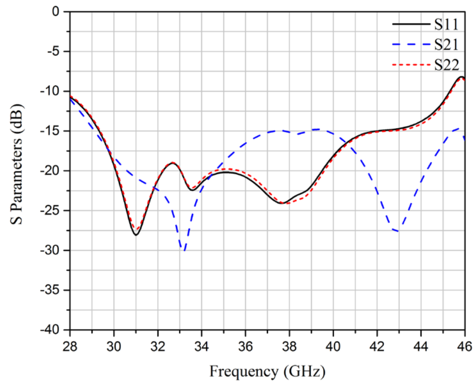


Fig. 4. Simulated reflection coefficient and isolation of the element.

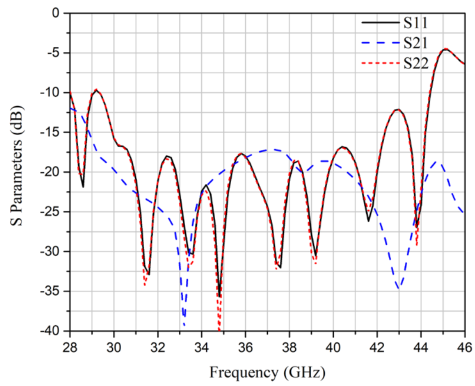


Fig. 5. Simulated reflection coefficient and isolation of the array antenna.

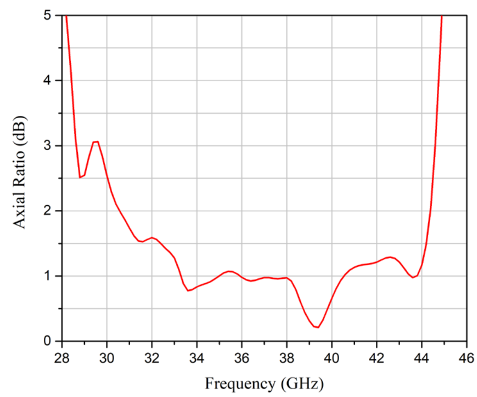


Fig. 6. Simulated axial ratio of the array antenna.

III. Simulation Results

Fig. 4 exhibits the simulated reflection coefficient and isolation between two ports of the isolated element. The reflection coefficient is less than -10 dB in the range of 28-45.4 GHz with over 47% bandwidth. The simulated reflection coefficient and isolation between two ports of the array antenna are shown in Fig. 5. It is seen that the relative impedance bandwidth is about 41.4% with the reflection coefficient less than -10 dB covering 29.3-44.4 GHz. Meanwhile, the isolation between two ports is almost greater than 15 dB in this frequency range. The impedance bandwidth of the array antenna is a little narrower than that of the isolated element because of the influence of network.

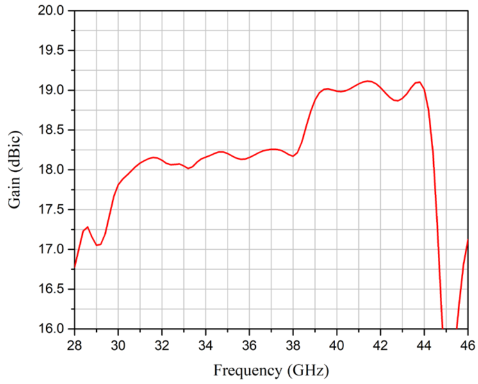
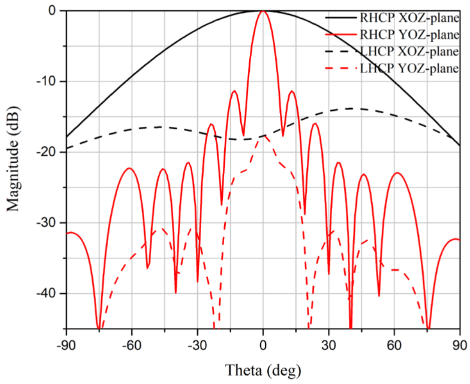
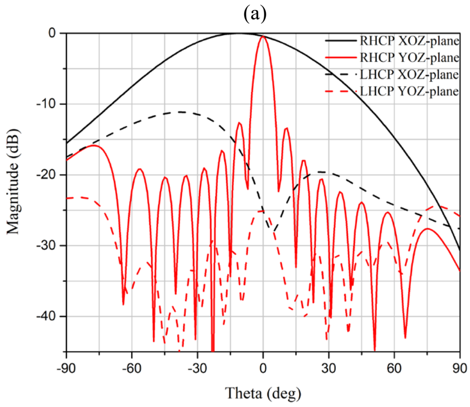


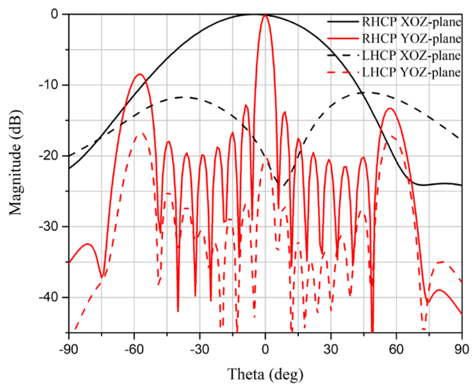
Fig. 7. Simulated gain of the array antenna.



(a)



(b)



(c)

Fig.8. Simulated radiation patterns of the array antenna. (a) 29 GHz. (b) 36.5 GHz. (c) 44 GHz.

Fig. 6 illustrates the simulated axial ratio of the array antenna. It is seen that 3-dB AR bandwidth is about 41.1% from 29.6 to 44.6 GHz. Fig. 7 presents the gain of the array antenna. The results indicate that the gain varies from 16.7 to 19.1 dBic within the operating band. Simulated radiation patterns of the array antenna at 29, 36.5, 44 GHz when port 1 is excited are shown in Fig. 8. The higher sidelobes at 44 GHz may be due to that the element spacing is about one wavelength.

IV. Conclusion

In this paper, a wideband dual-CP linear antenna array based on gap waveguide technology is proposed. The element consists of two groove gap waveguide layers and a septum polarizer that achieves dual-circular polarization. The proposed array antenna achieves 41.4% impedance bandwidth ranging from 29.3 to 44.4 GHz. Moreover, a 41.1% 3-dB AR bandwidth ranging from 29.6 to 44.6 GHz is realized.

Acknowledgment

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