Circularly Polarized Tightly Coupled Quarter-Circle Truncated Patch Array

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***Abstract*—This paper presents a circularly polarized (CP) tightly coupled quarter-circle truncated patch array. By reasonably cutting off two symmetrical quarter circles from the rectangular patches and arranging them in a tightly coupled array (TCA) configuration, the antenna array can achieve good circular-polarization performance. The simulation results indicate that the impedance and axial ratio (AR) bandwidth of the tightly coupled unit cell have reached 59.2% (2.58-4.75 GHz) and 24.6% (3.71-4.75 GHz), respectively, which are much wider than that of conventional truncated patches. In addition, a 4 × 4 TCA based on the proposed unit cell is implemented to validate the design concept.**

Keywords—circular polarization, quarter-circle truncated patch antenna, tightly coupled array (TCA)

I. INTRODUCTION

As a crucial role in wireless communication and radar systems, antennas have been put forward higher and stricter requirements as the development of such systems grow fast. It is of tremendous value to design low-profile, miniaturized and planar antennas, especially for space-sensitive applications. At the same time, the manufacture cost of antennas should be considered. For these reasons, the microstrip patch antenna has attracted considerable interests in recent years. However, the bandwidth of patch antennas tends to be a bottom neck for the applications of such kind of antennas. Tightly coupled arrays (TCAs) are proposed to meet these demands simultaneously, which can effectively broaden the antenna bandwidth because of the strong coupling effect between adjacent antenna elements. Moreover, it has become very competitive in various communication and radar systems because of its wide bandwidth, low cross-polarization level and good beam-scanning capability [1,2].

Various antennas applying TCA techniques have been proposed [3-6]. A broadband novel multi-feed tightly coupled patch array antenna (TCPAA) was proposed in [3], which features low-profile, wideband and high aperture efficiency compared with the traditional patch arrays. In [4], a planar ultrawideband wide-angle scanning TCA was designed, but the structure was relatively complex. Although these antennas exhibit good performance, they are all designed to radiate linearly polarized (LP) waves. However, circularly polarized (CP) antennas are more preferred by certain systems such as the satellite communication systems because of their merits of avoiding polarization mismatching and resisting multipath interference compared with the LP antenna [7,8], thus promoting the research on tightly coupled CP arrays (TCCA) [9-12]. In [9], a wideband CP tightly coupled crossed dipole array was proposed. By using the strong coupling between adjacent crossed dipole elements, the AR and impedance bandwidth can be improved. However, an absorber was needed to realize directional radiation and maintain good bandwidth performance. In [10], a millimeter-wave wideband TCCA using bold-C spiral elements was proposed. Though it exhibits excellent performance, the multilayer structure shows its disadvantages of high cost and implementation and fabrication difficulties.

In this paper, a simple patch antenna with two symmetrical quarter-circles corner truncated tightly coupled CP antenna array is presented, which meets the demand of low profile, low cost and wide bandwidth. The antenna unit cell is analyzed and optimized to achieve better CP performance. And a 4 × 4 array is designed to verify the effectiveness of the design methodology.

II. UNIT CELL DESIGN AND OPERATING THEORY

A. Unit Cell Design

As is indicated in Fig. 1, the geometry of the proposed unit cell is mainly composed of a corner truncated patch antenna, and a metallic reflector beneath the substrate. The patch antenna can be regarded as a rectangular patch cut off by two symmetrical quarter circles, which is a simple way to radiate CP waves. The patch is printed on the top side of the substrate and directly fed by a coaxial cable. The interior of the coaxial probe is connected to the patch and the exterior is connected to the reflector.

B. Operating Theory

As depicted from Fig. 1, two symmetrical quarter circles are cut off from the rectangular patch to realize circular polarization. Fig. 2 shows the current distributions of the patch antenna at four different phase states at 4.2 GHz, which reveals that the antenna radiates right-handed circularly polarized (RHCP) waves.

The impedance characteristics of the TCA depends on the performance of the unit cell, so it is very significant to analyze the geometry parameters that affect the impedance performance of the unit cell at first. Fig. 3 investigates three main geometry parameters that affect the impedance characteristics of the unit cell and the radiation pattern at 4.2 GHz. As shown in Fig. 3 (a), the high-frequency impedance bandwidth of the antenna becomes narrower with the increase of G_1, but the overall impedance matching is better. As can be seen from Fig. 3 (b), the larger G_2 is, the closer the reactance response is to zero, thus greatly improving the antenna impedance matching. However, it sacrifices the bandwidth of the high-frequency band and increases the antenna’s size at the same time. Fig. 3 (c) illustrates that a suitable H_1 (the height of the reflector to the patch), can slow the fluctuation of the impedance curve for better matching, thus efficiently enhancing the impedance

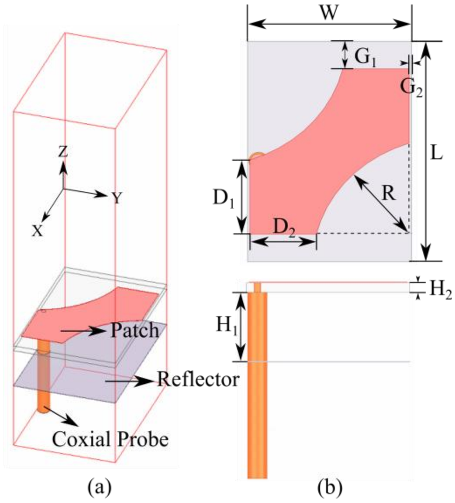

Fig. 1. Unit cell geometry. (a) Perspective view, (b) Top view and front view.

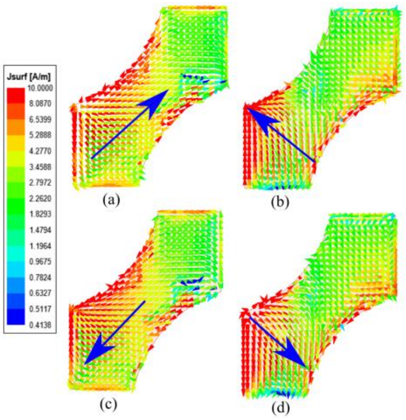

Fig. 2. Current distributions of the unit cell at 4.2 GHz. (a) Phase=0deg, (b) Phase=90deg, (c) Phase=180deg, (d) Phase=270deg.

bandwidth. And Fig. 3 (d) shows that the unit cell radiates a very uniform RHCP wave.

III. Simulation Results and Discussions

A. Optimization and Simulation Results of the Unit Cell

According to the above analysis, parameters G_1, G_2 and H_1 have a great influence on the impedance characteristics of the unit cell, and at the same time, these parameters also have an impact on the circular polarization performance of the antenna. Fig. 4 depicts the influence of G_1, G_2 and H_1 on ARs and reflection coefficients of the unit cell respectively. As G_1 becomes larger, the antenna gets better impedance matching, but the AR bandwidth move towards high-frequency band, resulting a decrease in the overlap between impedance and AR bandwidth. Similarly, when G_2 increases, the matching performance is greatly improved, but the overlapped bandwidth is also decreased. In addition, as H_1 increases, the AR bandwidth moves to the lower frequency band and the bandwidth becomes narrower. Moreover, the overall impedance characteristic gets worse. Therefore, these parameters need to be compromised in order to maximize the overlap of the impedance and AR bandwidth. As shown in Fig. 5, the optimized impedance bandwidth is from 2.58 to 4.75 GHz (59.2%), and the AR bandwidth is from 3.71 to 4.75 GHz (24.6%). It can be seen that the impedance and AR bandwidth are completely overlapped, which indicates that the antenna can realized CP radiation in a wide operating band.

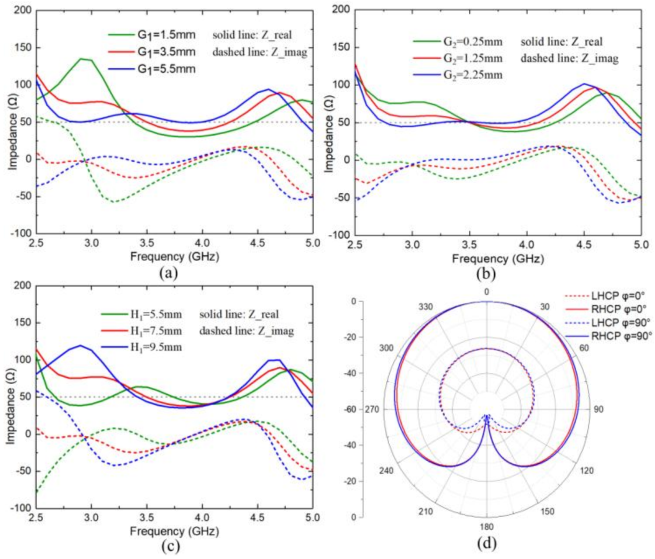

Fig. 3. The influence of parameters G_1, G_2 and H_1 on impedance curves respectively and the radiation pattern of the unit cell at 4.2 GHz. (a) G_1, (b) G_2, (c) H_1, (d) Radiation pattern.

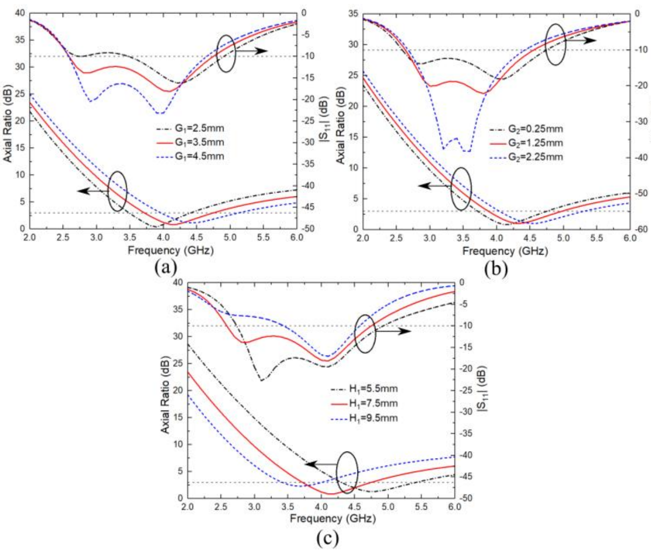

Fig. 4. The influence of parameters G_1, G_2 and H_1 on ARs and reflection coefficients of the unit cell respectively. (a) G_1, (b) G_2, (c) H_1.

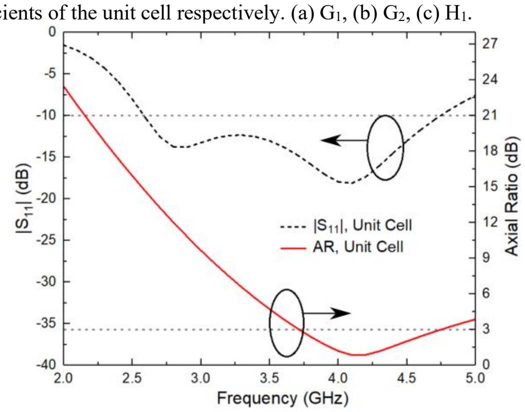

Fig. 5. The reflection coefficient and AR of the unit cell.

B. Simulation Results of 4×4 Tightly Coupled Array

Fig. 6 shows the configuration of the 4 × 4 tightly coupled array and its current distribution at 4.5 GHz. Fig. 7 shows the simulated AR and realized gain of the array respectively. As shown in Fig. 7, the AR bandwidth of the 4

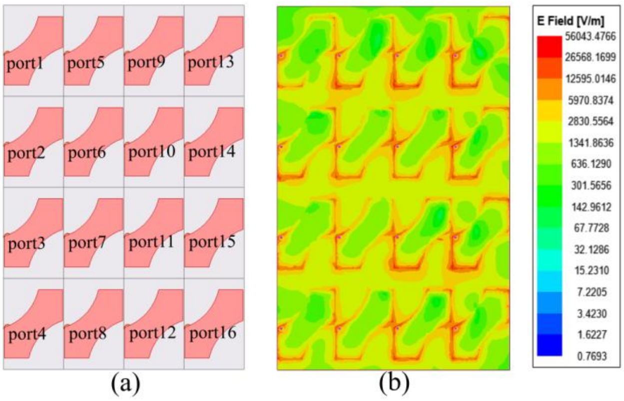

Fig. 6. 4×4 antenna array configuration. (a) Array layout and its feed ports, (b) Current distribution of the array at 4.5 GHz.

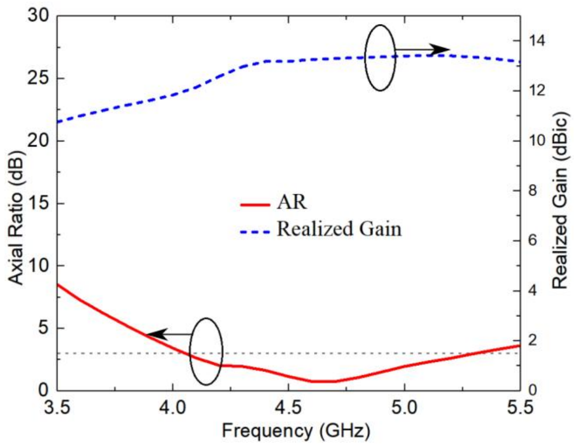

Fig. 7. Simulated AR and realized gain of the 4×4 antenna array.

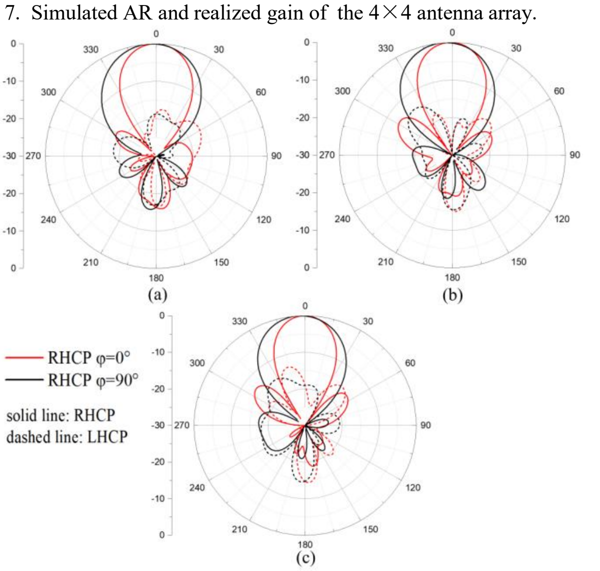

Fig. 8. Radiation patterns of the 4×4 antenna array at different frequency point. (a) 4.2 GHz, (b) 4.6 GHz, (c) 5 GHz.

×4 array is from 4.05 to 5.3 GHz (26.7%), and the realized gain is stable in the range of 11.85-13.36 dBic over the whole AR bandwidth. Fig. 8 reveals the radiation patterns of the array at three different frequency points. It is clear that the antenna can radiate RHCP waves with a front-to-back ratio (FBR) of 15 dB.

IV. Conclusion

In this paper, a CP tightly coupled unit cell is designed and a 4 × 4 array based on this unit cell is simulated to validate the design concept. By cutting off two symmetrical quarter circles from the patch, the corner-truncated patch unit cell can realize good CP performance. In addition, the unit cell can achieve a wide operating bandwidth under the strong coupling effects between adjacent elements. The finite 4 × 4 array is also analyzed and simulated, and its wide AR bandwidth, stable realized gain and radiation patterns make the antenna a suitable candidate for various wireless communication systems.

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