Novel Design Approaches to Planar End-Fire Dual-Band Circularly Polarized Antennas

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***Abstract*—In this paper, two design schemes for planar end-fire dual-band circularly polarized antennas (PEDBCPAs) are proposed. In the first scheme, a cavity is first used to achieve dual-band characteristic with vertical polarization, and then a rectangular loop and a planar printed dipole are employed to provide horizontal polarizations at 2.40 GHz and 5.0 GHz. Finally, a dual-band circularly polarized antenna with large frequency ratio is achieved. In another scheme, a single-band planar end-fire circularly polarized antenna is realized by using a cavity and a rectangular loop, and then a smaller inner loop is introduced to realize a dual-band circularly polarized antenna at 2.66 GHz and 2.74 GHz with a small frequency ratio. Both two designs do not introduce the extra phase shift line structure, and realize the PEDBCPAs with large and small frequency ratios.**

Keywords—Planar end-fire antenna, without extra phase shift line, dual-band, circular polarization

I. Introduction

Planar end-fire circularly polarized antenna (PECPA) has attracted lots of attention because its maximum radiation direction is in parallel with the antenna plane. Generally, there are two ways to implement the PECPAs. The first is the composition of the complementary dipoles [1], and the other way is to utilize combined magnetic dipoles [2]. Generally, most reported PECPAs are focused on single band with enhancing the bandwidth [3], gain [4], front-to-back ratio [5] and so on [6].

However, there are few works on planar end-fire dual-band circularly polarized antennas [7, 8]. Besides, they usually suffer from a relatively high design complexity. Therefore, two design schemes for planar end-fire dual-band circularly polarized antennas are proposed and discussed in this work. In the first scheme, a cavity is first used to achieve dual-band characteristic with vertical polarization. Then, a rectangular loop and planar printed dipole working at 2.40 GHz and 5.0 GHz are introduced for dual-band CP operation. In addition, in order to realize a small frequency ratio, an approach with two rectangular loops are proposed at the resonance frequency of at 2.66 GHz and 2.74 GHz. Both two designs exhibit low design complexity, and are able to realize the PEDBCPAs with large and small frequency ratios, which show a great potential for circular polarization and end-fire radiation applications.

II. Different Types of PEDBCPAs

In this section, two novel design approaches for PEDBCPAs will be discussed.

A. PEDBCPA with Dipole and Rectangular Loop

In the previous work, the cavity with the rectangular loop or the dipole can realize the single-band PECPA. However, it is rarely for the dual-band operation. To demonstrate the proof-of-concept, we use the rectangular loop with the cavity to generate the lower band, and introduce the dipole at the aperture of the cavity to achieve the upper band. The phase condition of circular polarization in upper band is fulfilled by the 90 degree phase difference between the electric and magnetic currents. In this way, the PEDBCPA is achieved. Fig.1 shows the geometry of the proposed antenna. It consists of three layers, two of them are utilized the Rogers5880 substrates. The structures of the cavity, dipole and loop are printed on Rogers5880 substrates. For the cavity, only one side is open while other three sides are shorted. Besides, two plastic screws are employed to support the structure. The height is set to be 5 mm to keeping a low profile.

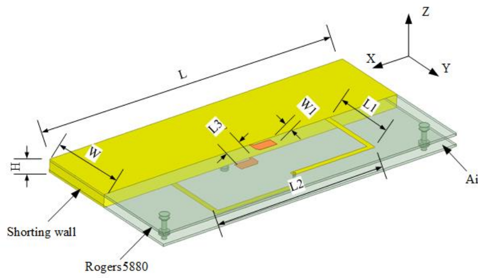

Figure 1. Geometry of the proposed antenna with dipole and rectangular loop.

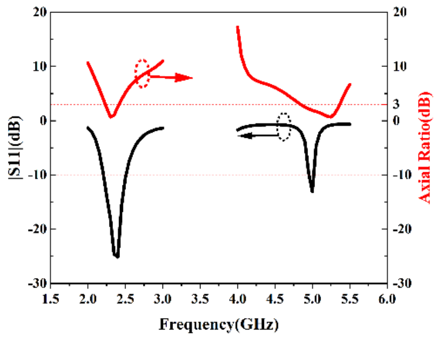

Figure 2. Simulated reflection coefficient and axial ratio of the proposed antenna with dipole and rectangular loop.

The simulation results are shown in the Fig.2. It can be clearly seen from the figure that the performance of dual-band CP operation is realized. According to the simulation results, it exhibits the -10-dB impedance bandwidths from 2.21 GHz to 2.51 GHz and 4.96 GHz to 5.02 GHz at the lower and upper band. Besides, the 3-dB axial ratio bandwidths range from 2.23 GHz to 2.42 GHz and 4.84 GHz to 5.37 GHz. The advantage of this method is the two bands can be independently tuned. In other words, by changing the length of the dipole element, the upper frequency and axial ratio at 5.0 GHz will be shifted while those of the lower frequency at 2.40 GHz is almost unchanged. In addition, when varying the dimensions of the loop element, only the lower frequency and axial ratio will be shifted and there is a very slight effect on the upper frequency. Finally, Fig. 3 plots the radiation patterns

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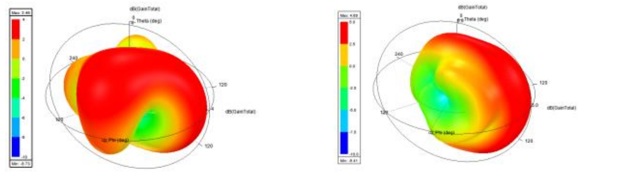


(a) (b)

Figure 3. Simulated radiation patterns of the proposed antenna with dipole and rectangular loop. (a) 2.4 GHz, and (b) 5.0 GHz.

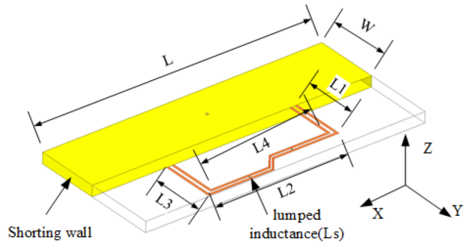


Figure 4. Geometry of the proposed antenna with two rectangular loops.

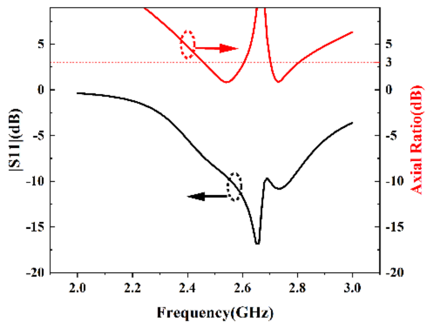
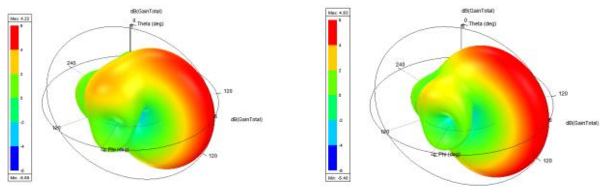


Figure 5. Simulated reflection coefficient and axial ratio of the proposed antenna with two rectangular loops.



(a) (b)

Figure 6. Simulated radiation patterns of the proposed antenna with two rectangular loops. (a) 2.54 GHz, and (b) 2.73 GHz.

at 2.40 GHz and 5.0 GHz. It is seen that, unidirectional beams at Y direction can be achieved. And the gain is about 2.9 dBic and 5.2 dBic at 2.40 GHz and 5.0 GHz, respectively. The dimensions of the proposed antenna are determined as follow: L =124 mm, W =31 mm, H =5 mm, $L1$ =24 mm, $L2$ =63 mm, $L3$ =8 mm, $W1$ =1 mm.

B. PEDBCPAs with Two Rectangular Loops

For the previous work, only one loop is employed for single band operation [2]. Motived by this work, a smaller inner loop radiator is introduced for dual band characteristics. Fig.4 shows the geometry of the PEDBCPAs with two rectangular loops. The proposed antenna exhibits a low profile with one single air substrate of 5 mm. The inner and outer loops contribute to 2.66 GHz and 2.74 GHz. The gap between them is very small, which would result in a strong coupling effect. It is found that two reverse currents are generated at these two loops, which is counteract each other. In this way, two axial ratio minima at 2.54 GHz and 2.73 GHz are attained. Besides, two lumped inductances are symmetrically added to improve impedance matching and axial ratio performances. The dimensions of the proposed design are determined as follows: L =133 mm, W =30 mm, H =5 mm, $L1$ =26.5 mm, $L2$ =65 mm, $L3$ =24.5 mm, $L4$ =61 mm, Ls =4 μH.

Fig. 5 shows the reflection coefficient and axial ratio of the proposed antenna. According to simulation results, it exhibits the -10-dB impedance bandwidths from 2.56GHz to 2.68 GHz and 2.70 GHz to 2.77 GHz at the lower and upper band. Besides, the 3-dB axial ratio bandwidths from 2.46 GHz to 2.61 GHz and 2.70 GHz to 2.81 GHz are attained. Fig. 6 plots the radiation patterns at 2.54 GHz and 2.73 GHz. It is seen that, unidirectional beams at Y direction also can be achieved. And the gain is about 2.84 dBic and 4.76 dBic at 2.66 GHz and 2.74 GHz.

III. Conclusion

This work presents two novel design approaches for PEDBCPAs. The cavity radiator is employed for dual-band operation with vertical polarization. In order to realize circular polarization with dual-band characteristic, the printed dipole and loop are designed for large frequency ratio design, while two loops are used for small frequency ratio. Two design examples of dual-band operation at 2.40/5.0 GHz and 2.66/2.74 GHz are demonstrated. All the results prove the effectiveness of the proposed design approaches.

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