Broadband Omnidirectional Circularly Polarized Antenna with High Gain

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***Abstract-* In this work, a broadband circularly polarized (CP) antenna with omnidirectional radiation and high gain is proposed for base station applications. The antenna consists of full wavelength strips, half wavelength strips and half wavelength loops in series, which ensure the in-phase currents along the antenna. The impedance bandwidth of the antenna is 3.3-3.89 GHz, whereas the axial ratio bandwidth is 3.35-3.97GHz. As a result, an overlapping bandwidth of 3.35-3.89GHz is achieved, mostly covering the band for 5G communications. The maximum antenna gain is 8.85 dBic.**

I. Introduction

With the rapid development and wide application of 5G technology, a large number of base station antennas are required at multiple bands to cover all the angles. Omnidirectional antennas are preferred to reduce the number of the antennas. At the same time, circularly polarized antennas are in demand for the avoidance of polarization mismatch. High gain is also critical to ensure the coverage distance.

Microstrip antenna array with circular polarization are widely utilized in base stations, with the demand of complicated feeding networks [1]. In [2], a broadband circularly polarized array is proposed. The antenna array is composed of four annular slots and a feeding network. The impedance bandwidth and the AR bandwidth of the array is 28.4% and 23.6%, respectively, with the gain of up to 13 dBi. In [3], a circularly polarized antenna array with a broad band of 40% and a gain of 17 dBi has been proposed. The antenna arrays can cover wide bandwidth and provide high gain, however, their angular coverage is limited and the occupied volume is large. Franklin antenna [4], which makes use of the inverse currents along the antenna can offer omnidirectional antenna with high gain. However, its bandwidth is normally narrow. The overlapped bandwidth of the impedance matching and the AR is normally less than 10% [5]-[6].

In this paper, a compact circularly polarized antenna with high gain and omnidirectional radiation is proposed, which is inspired from Franklin antenna. The overlapped bandwidth of 15% is achieved by the proposed antenna without complex feed network.

II. Antenna Configuration

The configuration of the proposed antenna is shown in Fig. 1. The antenna is composed of six metal rings and five metal strips in series, which operate as magnetic dipoles and electric dipoles, respectively. The balun, as given in Fig. 1(b), are employed for unbalanced feeding with the coaxial cable. Inspired by the Franklin antenna [4] and the CP antenna in [7], the antenna in Fig. 1 makes use of the inverse currents along the loops to achieve circular polarization. In [7], the circumference of the metallic ring and the length of the metal strips are half wavelength. According to [8], the gain of a full-wavelength dipole is much larger than that of the half wavelength dipole, without any side lobe in the pattern. At the same time, there is no reverse current along the metallic strip. Since the radiation of the series antenna is more affected by the structure closer to the feed, the central dipole of the proposed antenna is changed to a full wavelength dipole, whereas the length of the other metallic strips are maintained at half wavelength. Hence, the overall length is only slightly increased. The detailed antenna parameters are given in Table I.

Figure 2 shows the current distributions of the proposed antenna at 3.3GHz. It is seen that all the currents along the metallic strips are in phase. The arrangement of the loops determines the rotation direction of circular polarization. Clockwise rotation of the loop leads to right-hand polarization, and counter-clockwise rotation generates left-hand polarized antenna.

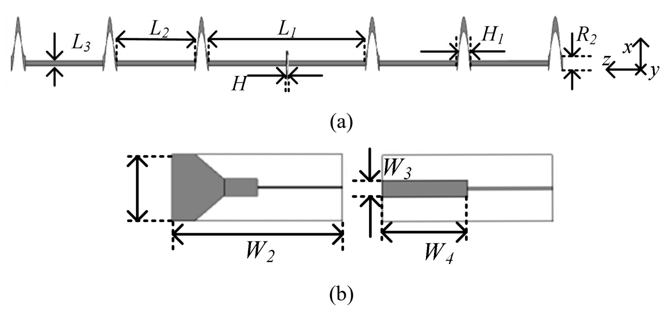

Figure 1. (a) Configuration of the proposed omnidirectional CP antenna; (b) Frontsize and backsize of balun.

TABLE I
Dimensions Of the Two-Antenna System (Unit: MM)

Parameters	L_1	L_2	L_3	W_1	W_2	W_3	W_4
Values	86.5	43	2	8.7	20.2	2.2	11
Parameters	H_1	R_2	H				
Values	7.7	5	0.767				

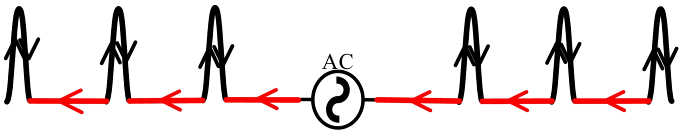

Figure 2. Current distributions of the proposed omnidirectional CP antenna.

III. Simulation Results

The simulated reflection coefficients of the proposed antenna are shown in Fig. 3, compared with the antenna with half-wavelength central dipole as the reference antenna (RA). The -10 dB bandwidth of the proposed antenna is 3.3-3.89 GHz, which is slightly narrower than that of the reference antenna. Figure 4 provides the AR bandwidth and gain of the proposed antenna and the reference antenna at phi=90˚. The AR bandwidth of the proposed antenna is 3.35-3.97 GHz, which is 40 MHz wider that the RA. The maximum gain is 8.85 dBic, which is 0.85 dB higher than that of the RA. The proposed antenna provides a larger gain over the operating band. The radiation patterns of the proposed antenna on the *xoy* and *yoz* planes are given in Fig. 5. It is seen that omnidirectional patterns are obtained on the horizontal plane, while the highest gain is deviated slightly from the *xoy* plane.

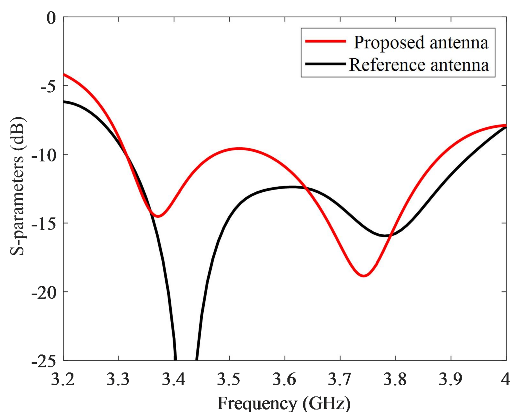

Figure 3. Simulated reflection coefficients of the proposed antenna and the reference antenna.

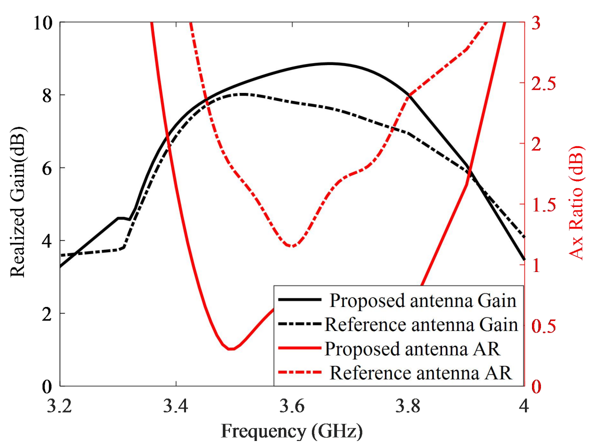

Figure 4 Simulated realized gain and axial ratio (AR) bandwidth (ϕ= 90°) .

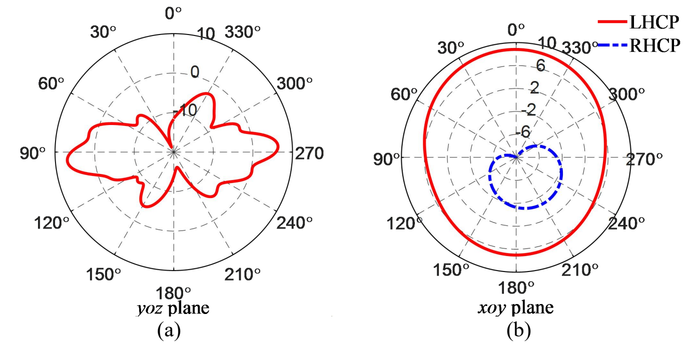

Figure 5. Radiation pattern of the proposed antenna at 3.7 GHz on (a) *yoz* plane; (b) *xoy* plane.

IV. Conclusion

In this work, a circularly polarized antenna is proposed based on the improvement of Franklin antenna. In the target frequency band, an overlapping wideband of 3.35-3.89 GHz is achieved, mostly covering the band for 5G communications. The LHCP antenna provides a highest antenna gain of 8.85 dBic and a lowest gain of 5.85 dBic over the operating band. Due to its slim and simple structure, the proposed antenna system is a promising candidate for 5G base stations in certain scenarios.

References

[1] C. F. Liang, Y. P. Lyu, D. Chen and C. H. Cheng, "Wideband Circularly Polarized Stacked Patch Antenna Based on TM_{11} and TM_{10}," *IEEE Trans. Antennas Propag.*, vol. 70, no. 4, pp. 2459-2467, April 2022.

[2] X. Jiang, Z. Zhang, Y. Li and Z. Feng, "A Low-Cost Wideband Circularly Polarized Slot Array With Integrated Feeding Network and Reduced Height," *IEEE Antennas Wireless Propag. Lett.*, vol. 15, pp. 222-225, 2016.

[3] Y. Qin, X. Mo, R. Li, T. Wong and Y. Cui, "A Broadband Wide-Beam Circularly Polarized Antenna Array for Urban Macrocell Base Stations," *IEEE Antennas Wireless Propag. Lett.*, vol. 67, no. 5, pp. 3478-3483, May 2019.

[4] C. S. Franklin, "Improvements in wireless telegraph and telephone aerials," British Patent GB242 342, Nov. 25, 1925.

[5] L. Chang, Y. Li, Z. Zhang and Z. Feng, "Horizontally Polarized Omnidirectional Antenna Array Using Cascaded Cavities," *IEEE Trans. Antennas Propag.*, vol. 64, no. 12, pp. 5454-5459, Dec. 2016.

[6] W. Lin and R. W. Ziolkowski, "High-Directivity, Compact, Omnidirectional Horizontally Polarized Antenna Array," *IEEE Trans. Antennas Propag.*, vol. 68, no. 8, pp. 6049-6058, Aug. 2020.

[7] W. Lin and R. W. Ziolkowski, "Compact, High Directivity, Omnidirectional Circularly Polarized Antenna Array," *IEEE Trans. Antennas Propag.*, vol. 67, no. 7, pp. 4537-4547, July 2019.

[8] Kraus J D, Marhefka R J. Antenna: For all applications (Third Editions), Publishing House Of Electronics Industry, 2011.