An Omni-directional Circularly Polarized Helical Antenna with an Inductive Feed

Yufeng Yu[1], **Xiaoyi He**[1], **Qi Liu**[2], **and Yufeng Wang**[1]

[1]China Jiangnan Electronics Communication Institute, Jiaxing 314000, China
[2]Center for Optical and Electromagnetic Research, Zhejiang University, Hangzhou 310027, China

Abstract— The paper presents an omni-directional circularly polarized (CP) helical antenna with an inductive feeding structure. The antenna is comprised of a printed helix with six arms on a thin rolled substrate and a feeding loop, which acts as the radiator and the feeding structure, respectively. The helix is fed by the feeding loop without physical connection through inductive coupling, which is convenient to achieve impedance matching. The 90° phase difference between the radiated horizontal and vertical electric field components is naturally guaranteed by the helix; therefore, circular polarization is achieved through tuning the height and radius of the helix to ensure equal magnitude of the radiated horizontal and vertical field components. With an electrical size of $0.17\lambda_0 \times 0.17\lambda_0 \times 0.11\lambda_0$, the antenna exhibits a simulated impedance bandwidth ($|S_{11}| \leq -10\,\mathrm{dB}$) of 5.72% and AR bandwidth (AR $\leq 3\,\mathrm{dB}$) of 27.4%.

1. INTRODUCTION

The omnidirectional circularly polarized (CP) antennas are very attractive in wireless communications. The omnidirectionality allows the antennas cover a large service area while the CP property not only support a free alignment between the receiving and transmitting antennas but also suppress the effects of multi-path reflections of waves caused by the nearby objects.

There are lots of reported works on omnidirectional CP antennas. Some of them utilize two radiators to generate vertical and horizontal polarized components of electric fields (E_θ and E_φ) with 90° phase difference, respectively. The radiator for E_θ can be top-loaded cylindrical monopole [1] or zeroth-order resonance (ZOR) antennas [2] and the radiator for E_φ can be printed arc-shaped dipoles [1] or monopoles [2]. Another design concept is to place several CP elements uniformly on the horizontal plane to form an omnidirectional radiation. In [3], four broadband CP rectangular loops are printed on a thin flexible dielectric substrate and rolled into a hollow cylinder. Fed by a broadband balun, this antenna exhibits a wide bandwidth and good CP property.

Normal mode helical antennas [4] with very small diameters are classical omnidirectional CP antennas. However, the feeding networks are usually needed for impedance mating, which increase the complexity of the antennas and the fabrication costs. A crossed parallel transmission line was proposed to feed a multifilar helical antenna [5] without any feeding network. However, the impedance matching is not good, and each helix needs to be separated and connected to the parallel transmission line, which is still not convenient for fabrication.

The inductively coupled feed using a small loop is an effective feeding technique [6, 7]. In this paper, this technique is utilized to feed a multifilar helical antenna. Compared with the crossed parallel transmission feeding line in [5], the inductively coupled feed can achieve better impedance matching to a $50\,\Omega$ feeding line and the tuning procedure is very easy. Additionally, there is no physical connection between the radiating helix and the feeding structure and the two parts can be fabricated respectively and then assembled easily, which eases the fabrication.

2. ANTENNA CONFIGURATION

The configuration of the proposed omni-directional circularly polarized helical antenna is shown in Figure 1(a). The antenna is comprised of a printed helix with six arms and a feeding loop, which acts as the radiator and the feeding structure, respectively.

Figure 1(c) shows the planar layout of the six-arm helix. It is first printed on a thin flexible substrate (Taconic TLY-5) with dielectric constant of 2.2 and thickness of 0.13 mm and then rolled up into a hollow cylinder of radius R_r. Each arm is with the width W_r and pitch angle α. A helical antenna can produce both vertical and horizontal components of the radiated electric fields (E_θ and E_φ) and 90° phase difference between the two components is naturally guaranteed [4, 8]. When α, H and R_r is tuned to ensure equal magnitude of E_θ and E_φ, the antenna can achieve good circular polarization of the radiated waves.

As shown in Figure 1(b), the feeing loop is printed on a Rogers RO4350B substrate with dielectric constant of 3.48 and thickness of 0.508 mm. Note that the loop is composed of two half loops printed on each side of the substrate. Each half loop is connected to the inner and outer conductor of a 50 Ω SMA connector respectively at one end and at the other end they are connected through a shorting pin. A 0.5 pF capacitor is inserted to the loop to add additional capacitance for impedance matching. Detailed dimensions of the antenna shown in Figure 1 are as follows: $R_r = 33.5\,\text{mm}$, $R_f = 15\,\text{mm}$, $W_r = 3\,\text{mm}$, $W_f = 3.5\,\text{mm}$, $l_e = 8.8\,\text{mm}$, $\alpha = 17.5°$, $H = 40.4\,\text{mm}$.

3. SIMULATED RESULTS AND DISCUSSIONS

The proposed antenna is simulated and optimized using HFSS v13. The simulated reflection coefficient is plotted in Figure 2. It is seen that the impedance bandwidth ($|S_{11}| \leq -10\,\text{dB}$) is 44.4 MHz (from 753.4 MHz to 797.8 MHz), which is approximately 5.72% at the center frequency 775.6 MHz. The average axial ratio (AR) in the azimuth (x-y) plane is also shown in Figure 2. It is noted that the simulated average AR is obtained by averaging the AR results in the azimuth (x-y) plane. It can be seen that the average AR is lower than 3 dB from 630.5 MHz to 831 MHz, which exhibits an AR bandwidth of 200.5 MHz.

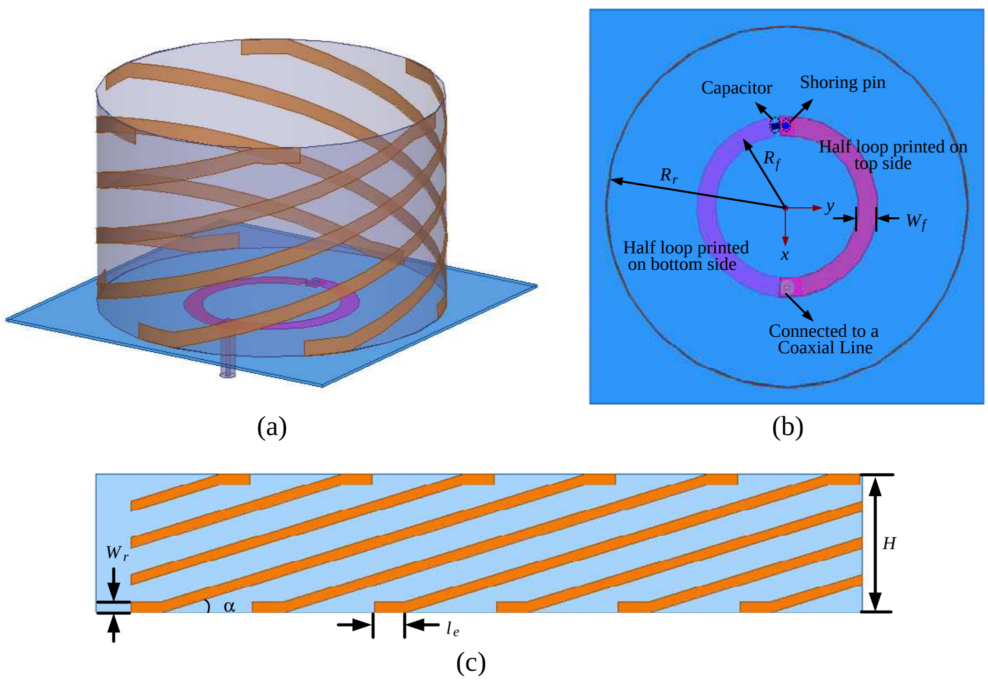

Figure 1: Antenna configuration: (a) 3-D view, (b) top view, and (c) planar layout of the helix.

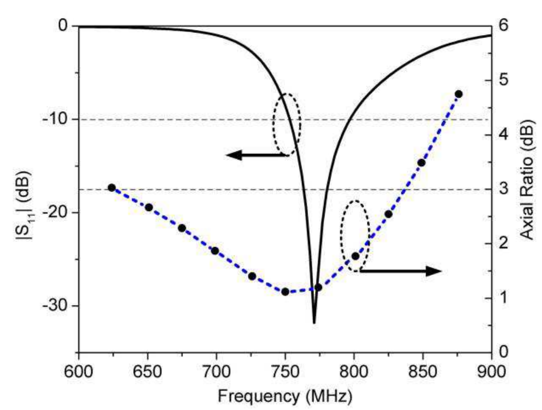

Figure 2: Simulated reflection coefficient and average axial ratio of the proposed antenna.

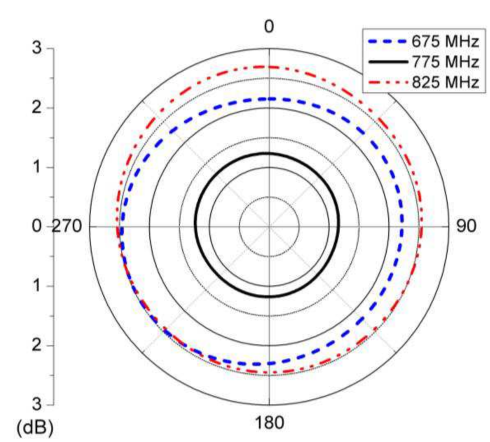

Figure 3: Simulated axial ratio of the proposed antenna in the azimuth plane.

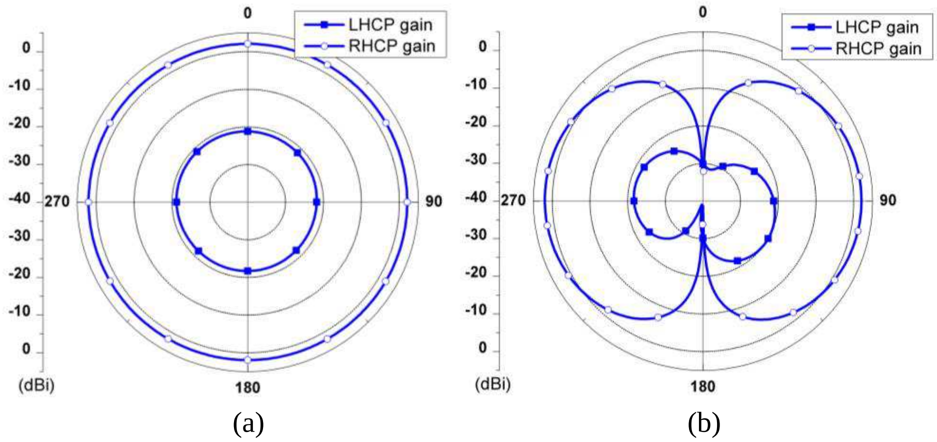

Figure 4: Simulated radiation patterns at 770 MHz. (a) Azimuth (x-y) plane, (b) elevation(x-z) plane.

The simulated axial ratio of the proposed antenna in the azimuth plane at 675 MHz, 775 MHz and 825 MHz are plotted in Figure 3. It is shown that the ripples are 0.33 dB, 0.11 dB and 0.26 dB at the corresponding frequency, which shows good symmetric AR in the azimuth plane.

Simulated radiation patterns at 775 MHz in the azimuth and elevation planes are plotted in Figure 4. The average LHCP gain is 2.02 dBi (1.94 dBi to 2.09 dBi) in the azimuth plane, while the average cross-polarization (RHCP) level is at about −21.50 dBi. It is seen that a very good omni-directional LHCP radiation pattern is achieved in the azimuth plane.

4. CONCLUSION

An omni-directional circularly polarized (CP) helical antenna with an inductive feeding structure is presented in this paper. With a size of 67 mm × 67 mm × 40.9 mm, the antenna exhibits a simulated impedance bandwidth ($|S_{11}| \leq -10$ dB) of 5.72% (753.4 MHz to 797.8 MHz) and AR bandwidth (AR ≤ 3 dB) of 27.4% (630.5 MHz to 831 MHz). The average right-handed CP gain in the azimuth plane is more than 1.4 dBi over the operating band ($|S_{11}| \leq -10$ dB).

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