Circularly Polarized Coplanar Crossed Dipole Antenna for RFID Handheld Reader

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1. Introduction

Radio frequency identification (RFID) system in the ultra-high frequency (UHF) band has been receiving much interest in several service industries, purchasing and distribution logistics, manufacturing companies and goods flow system [1]. The RFID system generally consists of the reader and the tag, and the UHF RFID system operates at the bands of North America (902-928 MHz), Taiwan (920-928 MHz) and Europe (865-867 MHz). The reader with an antenna sends a RF signal to a tag and receives a backscattered signal from the tag. The reader antenna is one of the important components in RFID system and has been designed with CP operation, because circularly polarized antennas can increase orientation diversity at the cost of polarization mismatch losses between the reader and the tag antenna. Moreover, a CP antenna with a low profile, small size, and light weight is needed in RFID handheld reader.

A typical technique for generating CP radiation is to excite two orthogonal degenerate resonant modes on the radiator with a 90^0 phase difference. Single-fed circularly polarized annular-ring, square and circular patch antennas with symmetrical or asymmetrical perturbation elements are reported [2]. Using perturbation cuts or strips to suitably differentiate the two orthogonal modes at resonant frequency, the antenna can easily radiate CP wave. However, those axial ratio (AR) bandwidths are usually narrow, which does not meet the bandwidth requirements in modern communication systems. For the design of the low profile patch antennas for the RFID reader applications, circular polarization can be generated from the slot-coupled radiation elements [3] or by employing a Wilkinson power divider feeding network [4]. Those feeding mechanisms are attractive for the broadband CP antenna designs for portable RFID applications, but those size are relative large for the requirement of handheld device. To improve the operating bandwidth and not increase the antenna size, using the planar crossed dipole antenna is a possible method. In [5, 6], it was shown that single-fed orthogonally crossed dipoles connected in parallel could generate CP radiation. If the lengths of the two dipoles were chosen such that the real parts of the input admittances are equal and the angles of the input admittances differ by 90^0 that the radiated wave in a normal direction will be circularly polarized. According to these conditions, several crossed dipole antennas were developed to improve the bandwidth and AR bandwidth [7, 8].

In this Letter, a small and single-layer coplanar crossed dipole antenna with meander arms has been proposed to obtain CP radiation. The proposed antenna uses two unequal length dipoles connected in parallel to a coaxial cable feed and requires no matching network. The antenna operates at its half wavelength of orthogonal modes for the UHF band, and the two resonant modes for CP radiation are generated by the unequal length of dipole arms. Details of the antenna design and the obtained experimental results are presented and discussed.

2. Antenna Design

The configuration of the proposed antenna is shown in Fig. 1, in which two meander arms of dipole antennas are etched on the same sides of FR4 substrate (50×50 mm^2) with thickness H1 = 1.6 mm and relative permittivity 4.4. The half-wavelength dipole antenna is a linearly polarized radiating structure consisting of two quarter-wavelength arms, which share a common feeding point at the centre of the substrate and are fed using a coaxial cable through a via-hole in the substrate.

Note that each dipole is arranged orthogonally in the diagonal line of the square substrate, and printed on the top side of the substrate. Each arm of dipoles was meandering to increase the resonant length for the requirement of small size. On the end of the arms for the two dipoles, different arrow lengths are added for a phase lag to generate the 90^0 phase difference. The optimized geometrical parameters obtained by HFSS are given in Table 1. The proposed antenna was designed and fabricated at 924 MHz (UHF band) to obtain the CP radiation. For the long dipole with the resonant length is 190 mm, corresponding to about 0.57 λ_0 of 900 MHz, and shows the simulated input impedance $Z_{in} = R_{in} + jX_{in} = 40.42 - j28.75\ \Omega$. According to the formula of $S_{11} = (Z_{in} - Z_0)/(Z_{in} + Z_0)$, the phase angle of S_{11} is about -90.7^0. Similarly, the resonant length of the short dipole is 174 mm (~0.55 λ_0) at 948 MHz with an input impedance of $16.07 - j0.415\ \Omega$, i.e., a phase angle of about -178.8^0. Clearly, the relative phase difference between the two dipoles is closed to 88^0; therefore, this design satisfies the phase requirement for CP radiation. Figure 2 shows the simulated phase diagram for the proposed antenna. It also be found that the two orthogonal modes (f_a = 900 MHz and f_b = 948 MHz) are excited in 88^0 phase difference and resulted in a good CP radiation.

3. Results and Discussions

The return loss is measured using an Agilent N5230A vector network analyzer, and axial ratio and radiation patterns are evaluated in anechoic chamber with an NSI-800F10 antenna measurement system. Fig. 3 shows the measured and simulated return loss of the proposed antenna. The measured impedance bandwidth for 10 dB return loss is 6.9%, ranging from 900 to 965 MHz, and agrees well with the HFSS simulated results (883-840 MHz). The measured and simulated axial ratio in the boresight direction versus frequency is also presented in Fig. 4. The 3-dB axial-ratio CP bandwidth is about 10 MHz or 1.0% around the center frequency at 924 MHz.

The measured and simulated radiation pattern at 924 MHz is plotted in Fig. 5, and good symmetry radiation has been observed. Note that a CP crossed dipole antenna without a reflector radiates a bidirectional wave, and the radiation patterns in both sides of the proposed antenna are about the same with contrary circular polarization; that is, the front-side radiates LHCP while back-side radiates RHCP. Also, it can be observed from the pattern that the 3-dB beam widths are about 80^0 with symmetry in both x-z and y-z plane. The measured and simulated gain was obtained using the gain transfer method where standard gain horn antenna was used as a reference, shown in Fig. 6. The obtained peak gain is from 0 dBi to 0.5 dBi in the UHF band (900-965 MHz) owing to the small size of the antenna.

4. Conclusion

A compact circularly polarized planar crossed dipole antenna with an unequal length of arms for RFID reader is designed and measured. It should be mentioned that owing to the use of only one layer substrate, this small structure has an inherent narrow bandwidth and gain. Experimental results show that the proposed antenna can have a 3-dB CP bandwidth of about 1.0% and an impedance bandwidth of about 6.9%. In addition, the proposed antenna is compact and easily to be embedded in the holding box as transmitting antenna in RFID handheld reader.

Acknowledgments

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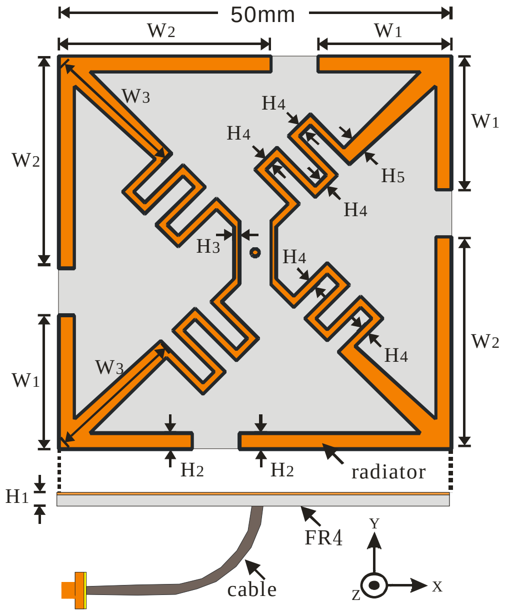

Figure 1: Geometry of the single-layer CP coplanar crossed dipole antenna.

Table 1: The parameters of the proposed antenna are in Fig. 1.

W1 = 12 mm	W2 = 22 mm	W3 = 19 mm
H1 = 1.6 mm	H2 = 2 mm	H3 = 1 mm
H4 = 1 mm	H5 = 2 mm	

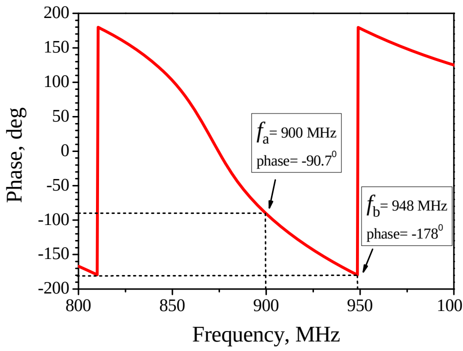

Figure 2: Simulated phase diagram versus frequency for the proposed antenna

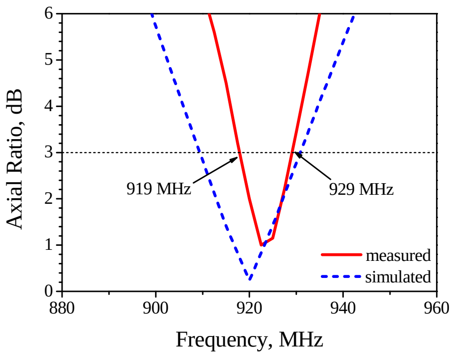

Figure 4: Measured and simulated axial ratio.

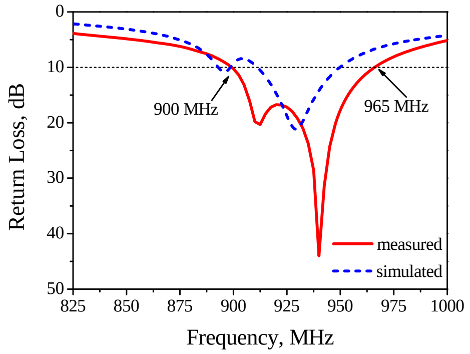

Figure 3: Measured and simulated return loss.

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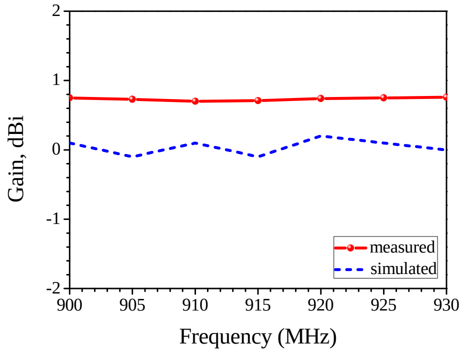

Figure 6: Measured and simulated antenna gain.

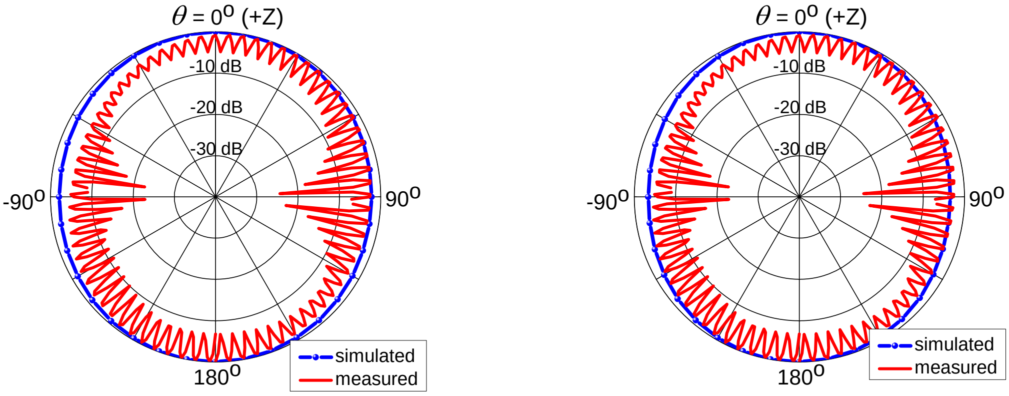

Figure 5: Measured and simulated normalized radiation pattern at 924 MHz. (a) x-z; (b) y-z plane.

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