A Wideband Circularly Polarized Antenna with Wilkinson Feed Network for Worldwide UHF Band RFID Reader

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Abstract— A radio frequency identification (RFID) reader antenna with circular polarization (CP) radiation is proposed to operate at worldwide UHF band which covers 840–960 MHz. The size of the antenna is $0.555\lambda_0 \times 0.553\lambda_0 \times 0.099\lambda_0$. A micro-strip patch with truncated corners as the main radiation patch is placed between the wilkinson feed network layer and the parasitic patch layer. The ground plate is placed on the top of the feed network layer. The feed network is connected with the main radiation patch via two metal cylindrical probes which produce two orthogonal signals of equal amplitude and 90 degree phase difference. The proposed antenna has wideband circularly-polarization characteristics. The truncated corners on the main radiation patch can increase 3 dB axial ratio (AR) bandwidth while improving the best axial ratio. And the parasitic patch can adjust the radiation direction of the antenna while increasing its gain. The simulation results show that the proposed circularly polarized UHF reader antenna has an input impedance matching bandwidth ($S_{11} \leq -10$ dB) of 456 MHz (675–1131 MHz), the band of reflection coefficient $S_{11} \leq -20$ dB covering 842–955 MHz, 3-dB axial ratio bandwidth of 296 MHz (741–1037 MHz), minimum axis ratio reaching 0.33 dB, and the highest gain reaching 3.53 dBi in the operating frequency band. Both the impedance bandwidth and the axial ratio band cover the entire UHF band of RFID systems.

1. INTRODUCTION

The use of radio frequency (RF) signals to identify objects is a practice that has been employed since World War II. However, back in those days, implementation of such devices was limited to specific applications due to high cost and big size of RF components [1]. Nowadays, the application area of radio frequency identification (RFID) is quite extensive, such as supply chain managements, health care, manufacturing, transportation, animal identification, asset management, logistics, identifying books in library and so on [2]. RFID systems are operated at widely different frequencies, such as LF (135 kHz), HF (13.56 MHz), UHF (840–960 MHz), and microwave Frequency (2.45 GHz and 5.8 GHz). However, according to the different standards in different regions/contries, the ultra-high frequency (UHF) is divided into different frequency ranges. For instance, UHF RFID applications is 840–845 MHz and 920–925 MHz in China, 865–869 MHz in Europe, 902–928 MHz in South America and North America, 908–914 MHz in Korea, 918–926 MHz in Australia, and 950–956 MHz in Japan [3]. Also, in the RFID system, the majority of tag antennas is designed as linear polarization (LP). Therefore, a circularly polarized reader antenna which can covers all UHF bands will have great application potential.

According to the total number of the feed points, the circularly polarized micro-strip patch antenna can be divided into three categories: single-feed-point circularly polarized micro-strip patch antenna, double-feed-point circularly polarized micro-strip patch antenna and multiple-feed-point circularly polarized micro-strip patch antenna. In order to cover China UHF band with a small size, a square radiation patch with two asymmetric circular slots antenna is proposed in [4]. It has an input impedance matching bandwidth ($S_{11} \leq -10$ dB) of 30 MHz (914–934 MHz), 3-dB axial ratio bandwidth of 6 MHz (919–925 MHz). A novel method of loading a semicircular slot into the main circular radiating patch is proposed in [5]. The L-shaped probe-feed technique gives the antenna a broader bandwidth (as well as 3-dB axial ratio bandwidth) than some antennas with a direct probe-fed structure. The antenna yields an impedance bandwidth (10-dB return loss) from 880 to 1100 MHz, while good CP performance between 901 to 930 MHz was demonstrated [5].

The proposed circularly polarized antenna has a good wideband performance and a broad 3-dB axial ratio bandwidth to fit the need for universal UHF RFID readers.

2. ANTENNA STRUCTURE AND DESIGN

A FR4 sub is used for the dielectric layer (relative permittivity of 4.4, loss tangent of 0.02) with a thickness of $h = 1.6$ mm. Figure 1 shows that the antenna containing a suspended conductor patch as the parasitic patch, a conductor patch with truncated corners as the main radiation patch and a Wilkinson feed network which is etched on the other side of the ground layer. The ground is etched on the top of the FR4 sub and the feed network is etched on the bottom of the FR4 sub. The antenna geometry is shown in Figure 2 and Table 1. The truncated corners are etched on the $90.8 \times 90.8\,\text{mm}^2$ main radiation patch placed on a layer of FR4. The ground plane has a size of $181.6 \times 181.6\,\text{mm}^2$ and the operating frequency band is set to 840–960 MHz. The parasitic patch has a size of $120.8 \times 120.8\,\text{mm}^2$ and is placed above the main radiation patch with a distance of 15 mm. And the main radiation layer (including the main radiation patch and a layer of FR4) is placed above the feed network layer (including the ground, the Wilkinson feed network and a layer of FR4) with a distance of 15 mm.

3. RESULT AND DISCUSSION

The simulated results of the S_{11} parameters, the AR, the gain for the reader antenna with the final optimized design parameters are shown in Figure 3. The simulation results show that the proposed circularly polarized UHF reader antenna has an input impedance matching bandwidth ($S_{11} \leq -10\,\text{dB}$) of 456 MHz (675–1131 MHz), the band of reflection coefficient ($S_{11} \leq -20\,\text{dB}$) covering 842–955 MHz, 3-dB axial ratio bandwidth of 296 MHz (741–1037 MHz), minimum axis ratio reaching 0.33 dB, and the highest gain reaching 3.53 dBi in the operating frequency band.

Table 1: The parameters of the antenna.

L_c	Delta	L	W	L_0	W_0	S	L_1	W_1
90.8 mm	0.018	$L_c * (1 + \text{Delta})$	$L_c * (1 - \text{Delta})$	$2 * L$	$2 * W$	8 mm	$L + 2 * G$	$W + 2 * G$
L_4	W_4	L_5	W_5	G	D	D_1	S_x	S_y
12 mm	3.02	18 mm	3.02 mm	15 mm	2 mm	6 mm	20 mm	20 mm
W_7	W_8	W_3	L_2	L_3	W_2	W_6		
3.02 mm	3.02 mm	1.57 mm	$L - W_2/2 - L_3 - L_4$	46.19 mm	3.02 mm	3.02 mm		

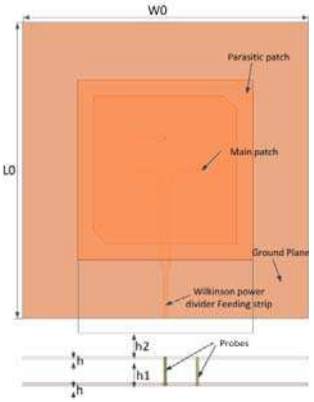

Figure 1: The structure of the reader antenna.

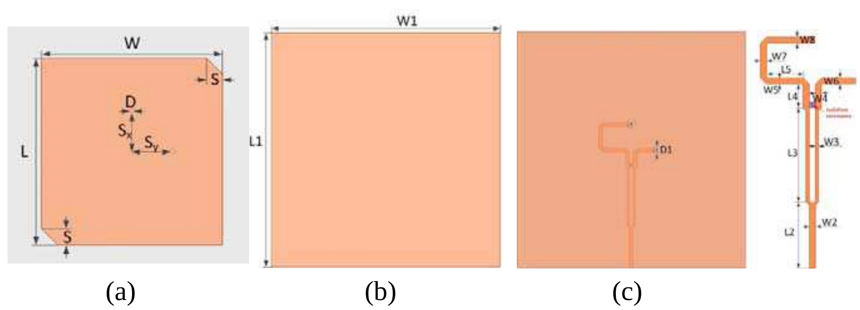

Figure 2: The geometry of (a) the main radiation patch; (b) the parasitic patch; and (c) the ground and the feed network.

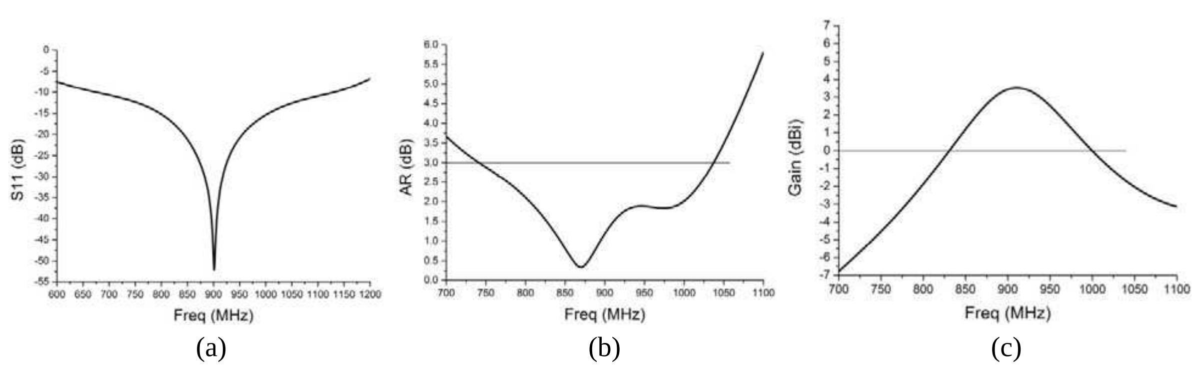

Figure 3: Simulation results for (a) S_{11} parameters, (b) AR, and (c) gain of optimized antenna.

The radiation patterns at 860 MHz, 900 MHz, 915 MHz and 922 MHz are shown in Figure 4. As can be seen, the radiation patterns has the shape of hemisphere while the 3-dB AR beamwidth is more than 60°.

We also conducted studies of the effects of the parameters Delta, G and S on the performance of the proposed antenna. Figure 5, Figure 6 and Figure 7 show how Delta, G and S affect the S_{11} parameters, the AR or the gain, respectively.

Figure 8 shows that the distance between the parasitic patch and the main radiation patch has a great influence on the S_{11} parameter. If the parasitic patch is removed, the antenna gain will be reduced significantly and it will not work properly.

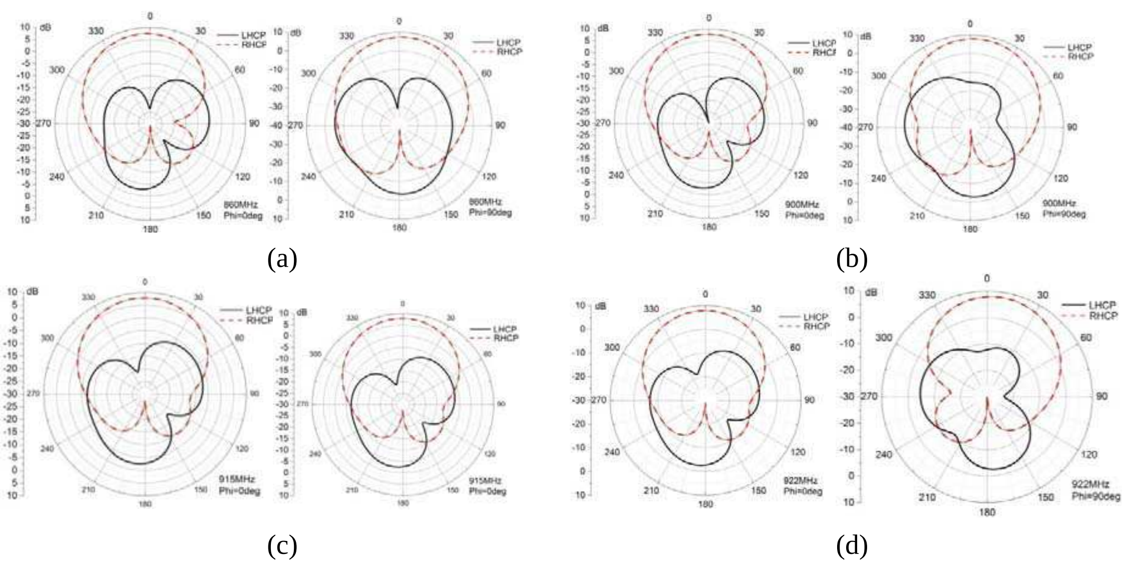

Figure 4: The radiation patterns at (a) 860 MHz, (b) 900 MHz, (c) 915 MHz, and (d) 922 MHz.

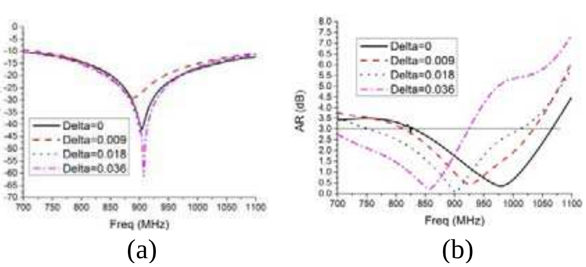

Figure 5: Simulation results for (a) S_{11} parameters and (b) AR for different Delta.

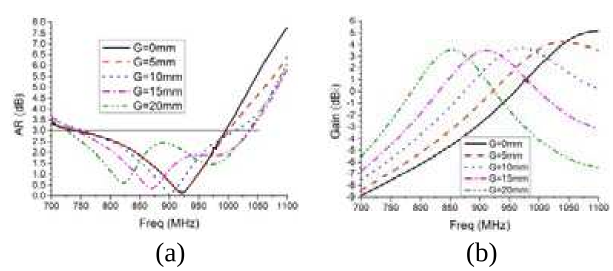

Figure 6: Simulation results for (a) AR and (b) gain for different G.

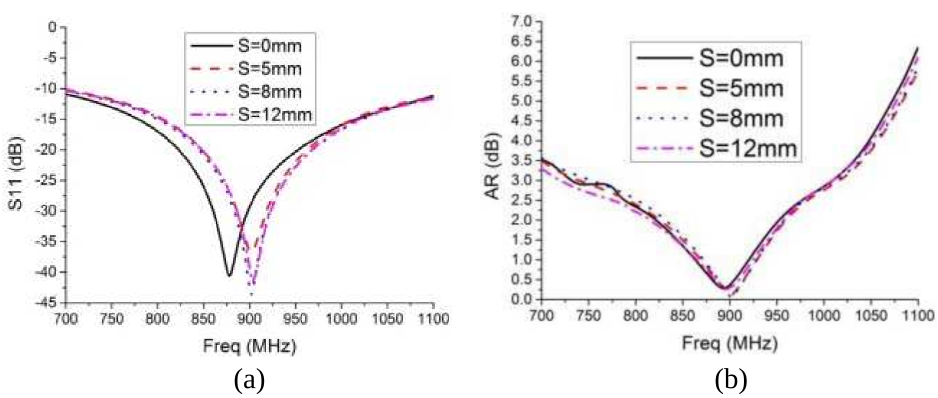

Figure 7: (a) S_{11} Parameters, (b) AR simulation results due to different S.

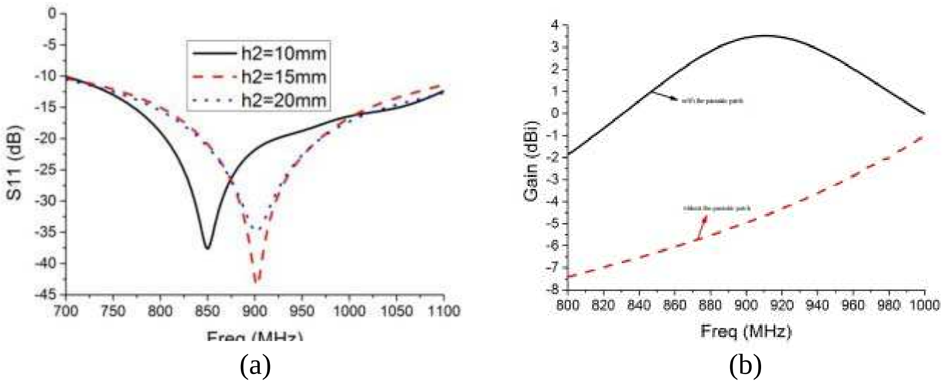

Figure 8: Simulation results (a) S_{11} for different h_2, and (b) the gain with or without the parasitic patch.

4. CONCLUSION

In this paper, a universal wideband circularly polarized UHF RFID reader antenna has been presented. By using a Wilkinson feed network and a parasitic patch, the designed antenna can cover the entire UHF band of RFID systems (for both the impedance and the axial ratio band). Especially the minimum axis ratio can reach 0.33 dB, and the highest gain can reach 3.53 dBi in the operating frequency band. The radiation field of the antenna has a shape of hemisphere while the 3-dB AR beamwidth can be larger than 60°. The universal antenna should be useful for low-cost RFID system.

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