Circularly Polarized Antenna with Circular Shaped Patch and Strip for Worldwide UHF RFID Applications

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***Abstract*– A circularly polarized Radio Frequency Identification (RFID) reader antenna is proposed for worldwide Ultra-High Frequency (UHF) (840–960 MHz) applications. The antenna is composed of two circular shaped patches, a ring shaped strip, and a suspended conducting strip with open-circuited termination. The simulations show that the antenna has an impedance bandwidth (S11 < –25 dB) of about 17.4% (807–961 MHz), 3-dB axial ratio (AR) bandwidth of about 14.4% (833-962 MHz), 2-dB AR bandwidth of 12.9% or 842-958 MHz, and gain level of about 9.1 dBic or larger within the 3-dB AR bandwidth. The proposed antenna can be a good candidate for universal UHF RFID readers at the UHF band of 840–960 MHz, which has excellent impedance matching (S11 < –25 dB), high gain (Gain > 9.1 dBic), and good AR (AR< 2 dB) performance.**

***Index Terms*— Broadband antenna, circularly polarized (CP), axial ratio (AR), impedance matching, ultra-high frequency (UHF).**

I. INTRODUCTION

Radio Frequency identification (RFID) is a technology that can be used to identify any object that carries an electronic tag by electromagnetic waves [1]. The design of antennas for RFID application has been playing a crucial role in the continuous development of this technology. Owing to the advantages of long detection range, fast reading speed and high data transfer rate, passive RFID systems at ultra-high frequency (UHF) band are preferred in many applications, such as animal tagging, supply chain management, and electronic payment. However, the UHF frequencies authorized for RFID applications are particular in different countries and regions [2-3], for example, 840.5–844.5 and 920.5–924.5 MHz allocated for China, 866–869 MHz for Europe, 920–926 MHz for Australia, 866–869 MHz, 923–925 MHz for Singapore, 902–928 MHz for North and South of America, and 952–955 MHz for Japan. Therefore, if the entire band of 840-955 MHz is covered, the implementation and cost of RFID systems can be simplified and reduced. As is known, the RFID system consists of reader and tag, and the antennas in tag are normally linearly polarized. Considering the arbitrary orientation of the tags, circularly polarized (CP) antennas are required in UHF RFID readers to avoid severe polarization mismatch between readers and tags [4-5]. CP antennas can be obtained by exciting two spatial orthogonal modes of equal amplitude with a 90° phase difference [6]. Various CP reader antennas for UHF RFID system have been researched. A planar reader antenna covering the ultra-high frequency band of 860–960 MHz is presented in [7] by insetting grounded arc-shaped strip to a square slot and feeding it with F-shaped microstrip line. A crossed dipole reader antenna with phase delay lines is designed in [8], which has a 3-dB axial ratio (AR) band of 905–935 MHz. An aperture-coupled patch antenna for RFID reader with a Wilkinson power divider feeding network is realized in [9], whose 3-dB bandwidth is 909–921 MHz. The mentioned antennas either have a bidirectional radiation pattern or suffer narrow bandwidth, low gain, and complex feeding structure. Hence, a number of stacked patch antenna have been studied recently [1], [6] to achieve broadband CP antenna with high gain and the compromise between performance and complexity.

Comparing with the common square shaped patch CP antenna [6], in this paper, a stacked circular shaped patch CP antenna for UHF RFID applications is designed. The antenna comprises two suspended circular shaped patches, a ring shaped strip and a conducting strip. The main patch is sequentially fed by four probes. A parasitic patch is positioned right above the main patch for improving the bandwidth. In particular, to enhance the performance of AR and impedance matching, the central parts of the two patches are cut off, two slots and a ring shaped strip are added to the main patch on the diagonal and the edge of the parasitic patch, respectively. Finally, the proposed antenna achieves better performance in terms of AR (AR < 2 dB), impedance matching ($S11 < -25$ dB), and gain (Gain > 9.1dBic) in the band of 840–960 MHz.

II. ANTENNA CONFIGURATION

Fig. 1 shows the configuration of the proposed antenna in detail. The antenna is composed of two radiating patches, a suspended conducting feed strip, a ring shaped strip, and a finite- size ground plane. The conducting feed strip with a width of 26 mm is suspended above the ground plane ($250\ \text{mm} \times 250\ \text{mm}$) at a height of $\text{h1} = 5\ \text{mm}$. Two cuts ($15\ \text{mm} \times 2\ \text{mm}$) near the feed point are introduced to enhance the impedance matching. According to previous studies [10], thick air substrate can be used to enhance bandwidth and gain. And the large reactance caused by the thick air spacing and the long probes can be effectively cancelled out with the effect of the strong electromagnetic coupling between the circular shaped conducting strip and the radiating patch [11]. Also, this is an

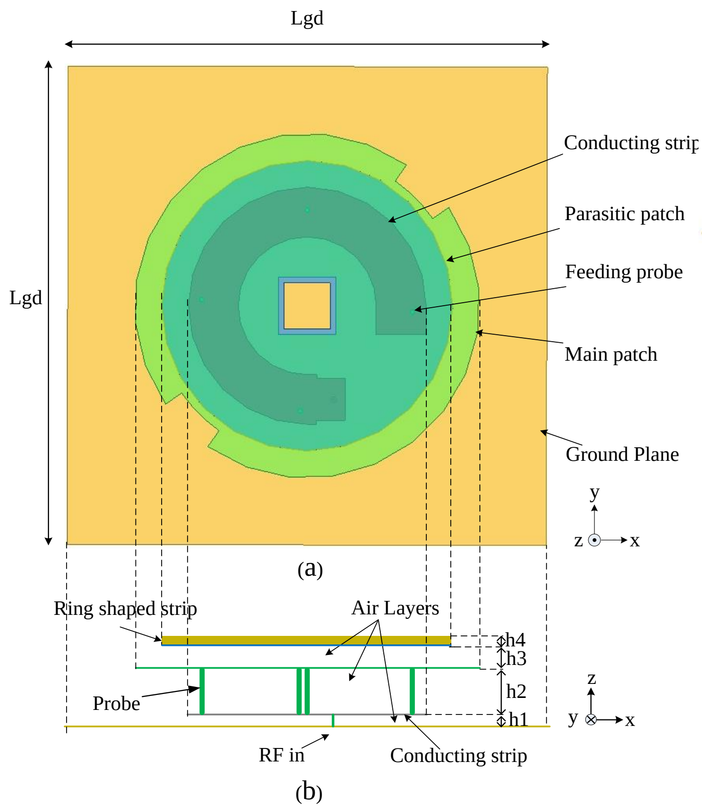

Figure 1. Configuration of the proposed antenna. (a) Top view. (b) Side view.

important approach to achieve a good impedance matching and broad AR bandwidth. Along this train of thought, large spacing of $h2 = 20$ mm between the feeding line and the main patch of $Ra = 90$ mm is adopted. Two slots with radian of 20° and $Lc = 10.2$ mm is made on the diagonal of the main patch to further widen the AR bandwidth. The main patch and conducting strip are connected by four probes with diameter of 2.2 mm. The position of the probes are optimized along the conducting strip to create 90° phase difference between the probes and two spatial orthogonal modes of equal amplitude that are two necessary conditions to achieve circular polarization. To broaden the bandwidth, a parasitic patch with a dimension of $Rb = 76$ mm is placed above the main patch with the spacing of h3=10 mm. A squared patch is removed with a dimension of $Lm = 30$ mm and $Lp = 24$ mm in the center of the main patch and parasitic patch, respectively, strengthening interaction between the main patch and parasitic patch to further enhance the performance of AR. In particular, a ring shaped strip of $h4 = 4$ mm are added along the edge of parasitic patch to improve the ration pattern and the AR performance. Fig.2 shows the detailed dimensions with separated parts.

III. SIMULATION RESULTS AND ANALYSIS

Simulations of the designed structure were carried out by using Ansoft HFSS software based on finite element method (FEM). The simulation results show that the antenna has exc-

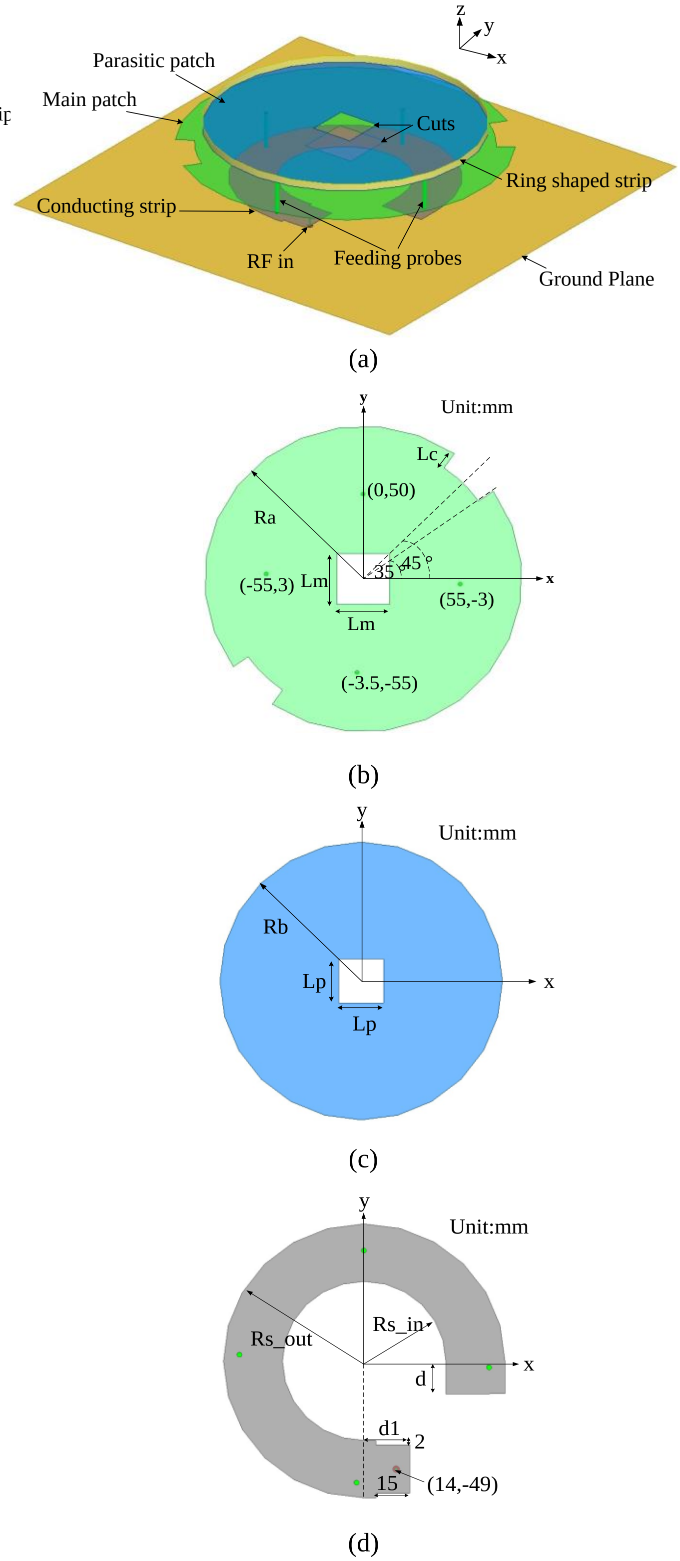

Figure 2. Antenna detailed dimensions. (a) Antenna structure. (b) Main patch. (c) Parasitic patch. (d) Conducting feed strip.

ellent impedance matching, good circular polarization, high gain, and hemispherical radiation pattern.

Fig.3 (a) gives the S11 of the antenna. The simulated S11 is less than –25 dB over the frequency range of 807–961 MHz. As shown in Fig.3 (b), the 3-dB axial ratio bandwidth is about 129 MHz from 833–962 MHz or 14.4%, with a minimum axial ratio of 0.36 dB at 860 MHz, and most of the AR is below 2 dB in the operating bandwidth (840–960 MHz). Fig.3(c) exhibits the antenna gain. It is observed that the antenna gain is 9.1 dBic or even larger within the operating bandwidth (840–960 MHz), with a peak gain of 9.8 dBic.

Fig. 4 shows the simulated radiation patterns at 840, 910, and 950 MHz, respectively, in the x-z and y-z planes. It is observed that the radiation patterns are almost symmetrical in both planes, and the 3-dB AR beamwidth is about 69 °. A further work can be done to widen the 3-dB AR beamwidth, which may be disturbed by some asymmetric parts of the proposed antenna. In addition, the front-to-back ratio of the antenna is better than 15 dB at all operating frequencies, although a finite size ground plane is used. Therefore, a CP antenna with good performance has been designed for the worldwide UHF RFID reader.

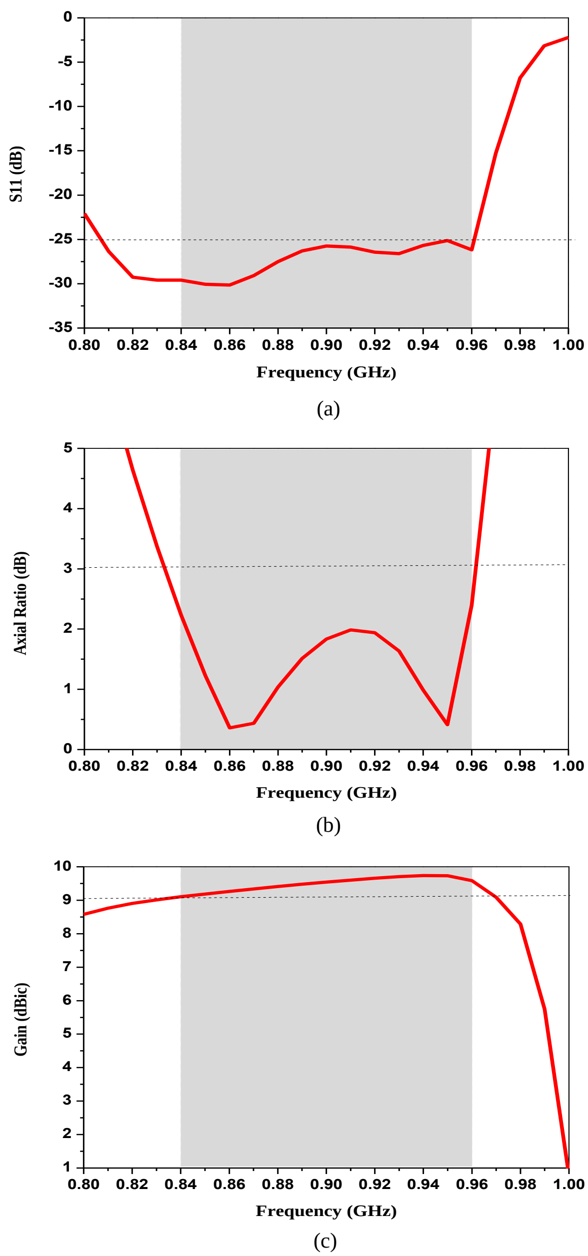

Figure 3. Simulated results of the proposed antenna. (a) S11. (b) AR. (c) Gain.

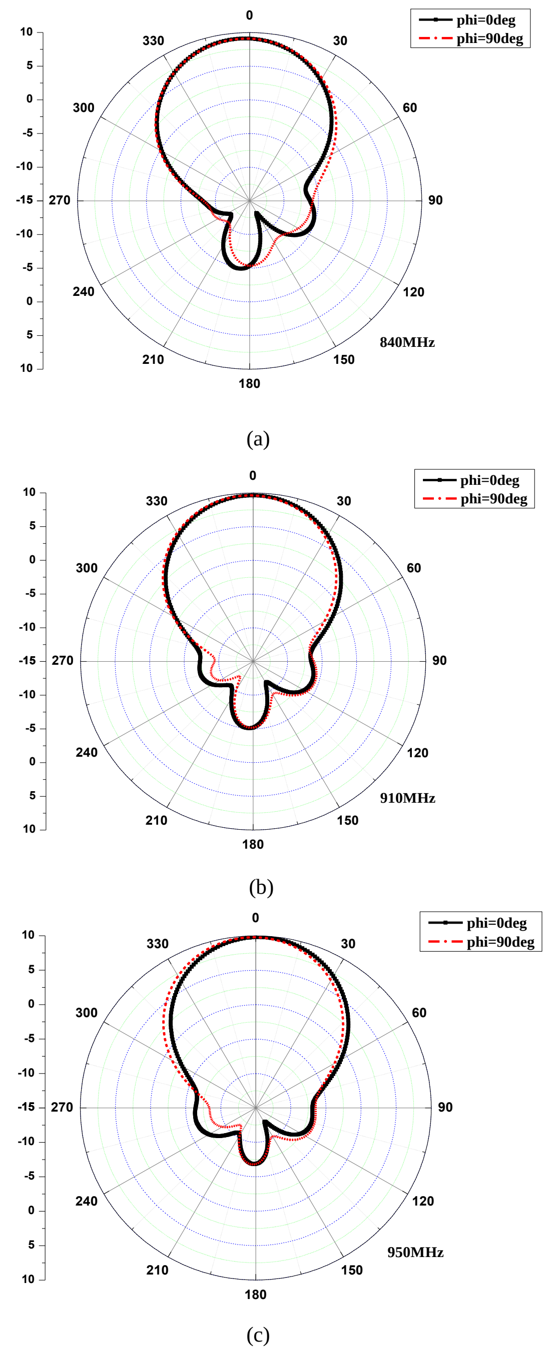

Figure 4. Simulated radiation patterns of the proposed antenna. (a) 840 MHz. (b) 910 MHz. (c) 950 MHz.

IV. CONCLUSIONS

Comparing with many of the previous works focusing on the design of feeding network, this paper attempts to do some research on the structure of the radiating patches to achieve better performance of the antenna in RFID reader. A broadband circular shaped patch antenna for worldwide UHF (840–960 MHz) RFID applications has been presented. By using sequential feed, stacked structure and added ring shaped strip, the simulation results show that the proposed antenna has an impedance bandwidth (S11 <–25 dB) of 17.4% or 807–961 MHz, 3-dB AR bandwidth of 14.4% or 833–962 MHz, 2-dB AR bandwidth of 12.9% or 842-958 MHz and gain level of 9.1 dBic or even larger within the operating bandwidth. Therefore, the proposed CP antenna can be universal UHF RFID reader antenna.

The next work will be done to make physical antenna model and measure reading rang.

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