Planar Circularly Polarized Circular Antenna with Clover Slot for RFID System

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***Abstract* - A novel circularly polarized (CP) circular antenna for UHF RFID system is proposed and experimentally studied. By embedding a four-leaf clover slot into the circular patch fed by the L-shaped microstrip line, the proposed CP design can easily be achieved with the impedance bandwidth (RL ≧ 10 dB) of about 99 MHz (11.0% @ 925 MHz) and the 3 dB axial-ratio (AR) bandwidth of about 60 MHz (7 % @ 925 MHz) for UHF RFID applications. The measured peak gain and radiation efficiency are about 6.2 dBic and 90% across the operating band, respectively, with unidirectional pattern in the XZ- and YZ-plane.**

***Index Terms* — Circularly polarized, RFID, UHF.**

1. Introduction

Due to the merit performance such as longer reading distance, fast reading speed and large information storage capability, UHF (860–960 MHz) band radio-frequency identification (RFID) system becomes more attractive for many industrial services such as supply chain, tracking, inventory management and bioengineering applications. The RFID reader antenna is one of the important components in RFID system and has been designed with CP operation to receive the RF signal that emanates from arbitrarily oriented tag antennas for improving the reliability of communications between readers and tags. Moreover, circularly polarized antennas can reduce the loss caused by the multi-path effects between the reader and the tag antenna. However, the UHF frequencies authorized for RFID applications are varied in different countries and regions. Hence, a universal reader antenna with desired performance across the entire UHF RFID band operated at 860–960 MHz (a fractional bandwidth of 11.1%) would be beneficial for the RFID system configuration and implementation to overcome the operating frequency shift and impedance variations due to the manufacturing process errors. Circular polarization can be obtained by exciting the two orthogonal linearly polarized modes with a 90° phase offset. Numerous CP reader antennas for UHF RFID system have been presented such as the aperture-coupled annular ring patch antenna with thick high-dielectric substrate [1], a sequentially fed stacked corner-truncated CP patch antenna [2], the stacked patch antenna composed of two corner-truncated patches with a horizontally meandered strip [3], a circularly polarized patch antenna excited by an open circular ring microstrip line through multiple slots [4], asymmetric-circular shaped slotted microstrip antenna [5]. However, to overcome the disadvantage of bulky volume [1, 3-4] or complex structure [2], in this article, we present a novel CP design of planar UHF RFID reader antenna with uni-directional reading pattern. This circular antenna embedded with a four-leaf clover slot is fed by the L-shaped microstrip line to obtain the wider CP operating bandwidth. The obtained impedance bandwidth (RL ≧ 10 dB) across the operating band can reach about 99 MHz (11.0% @ 925 MHz) and the 3 dB axial-ratio (AR) bandwidth of about 60 MHz (7 % @ 925 MHz). With unidirectional reading pattern, the maximum antenna peak gain and radiation efficiency across the operating band are about 6.2 dBic and 90%, respectively. Details of the proposed UHF RFID reader antenna design is described and its experimental results from the obtained CP performance as operating at 900 MHz band are presented and discussed as well.

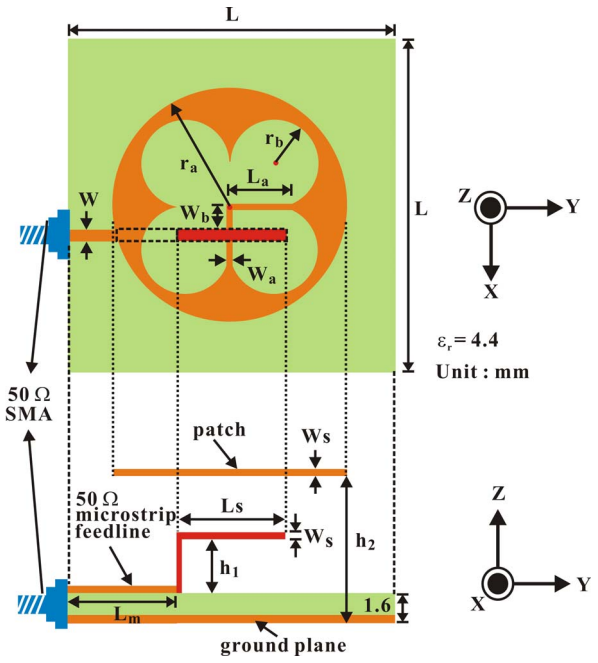

Fig. 1. Geometry of the proposed planar broadband circularly polarized antenna for UHF RFID Reader.

2. Antenna design and experimental results

The geometry of the proposed circularly polarized circular antenna is illustrated in Fig. 1. The circularly polarized antenna with the total antenna size of 150 × 150 mm^2 is printed on an FR4 substrate (ε_r = 4.4, thickness =

0.8 mm, loss tangent = 0.0245). This radiating circular patch is set to be with the radii of 55 mm. Then, four circular slots with the radius of 23 mm are embedded into the circular radiating patch to form a clover slot. An inverted L-shaped strip is added into the above slot for an unsymmetrical structure. An L-shaped micrstrip line is introduced to excite dual resonant modes with 90 degrees phase difference for a wider CP operating bandwidth at UHF band.

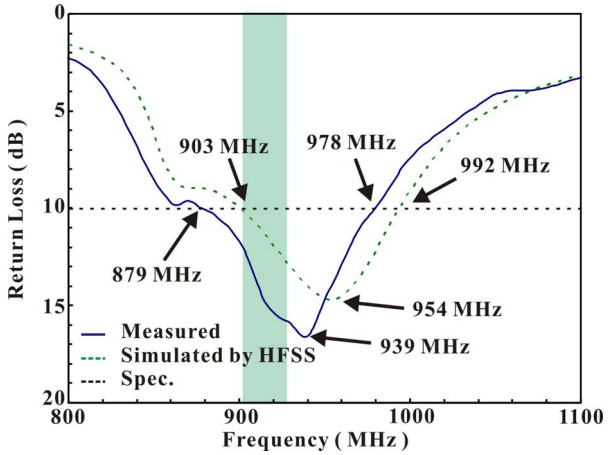

Fig. 2. Simulated and measured return loss against frequency for the planar circularly polarized circular antenna.

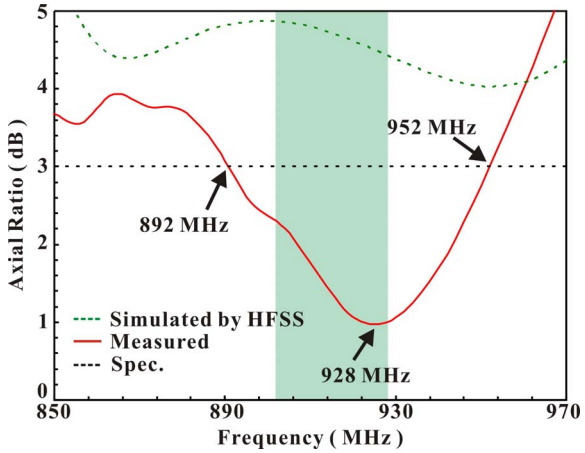

Fig. 3. Simulated and measured axial ratio against frequency for the planar circularly polarized antenna.

The electromagnetic simulator HFSS based on the finite element method [6] has been applied for the proposed tag antenna design. Fig. 2 and 3 show the related simulated and experimental results of the return loss and axial ratio (in the boresight direction), respectively, for the proposed CP antenna of Fig. 1. From the related results, the measured impedance bandwidth (RL ≧ 10 dB) across the operating band can reach about 99 MHz (11.0% @ 925 MHz) and the 3 dB axial-ratio (AR) bandwidth of about 60 MHz (7 % @ 925 MHz), which is suitable for American (902~928 MHz), European (918~926 MHz) and Taiwanese UHF RFID (922~928 MHz) applications. The CP radiation pattern measured at 920 MHz is plotted in Fig. 4, and good unidirectional radiation has been observed. The maximum measured peak antenna gain and radiation efficiency is 6.2 dBic and 90% across the operating band, respectively.

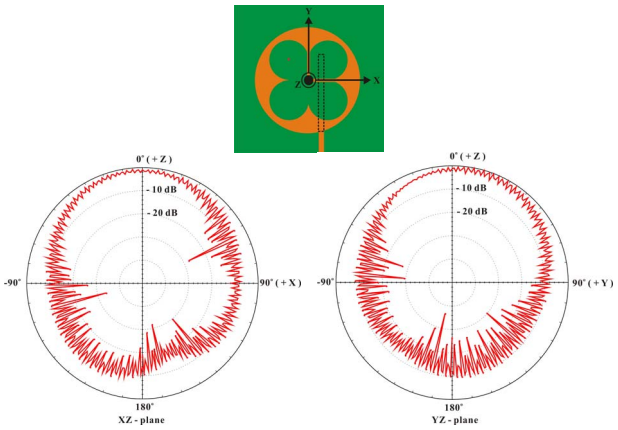

Fig. 4. Measured normalized CP radiation patterns for the proposed CP antenna at 925 MHz.

3. Conclusions

A novel circularly polarized circular antenna fed by an L-shaped microstrip line is proposed for the application of UHF RFID system. The obtained impedance bandwidth across the operating band can reach about 99 MHz (11.0% @ 925 MHz) and the 3 dB axial-ratio (AR) bandwidth of about 60 MHz (7 % @ 925 MHz) for UHF RFID applications, which can cover American (902~928 MHz), European (918~926 MHz) and Taiwanese UHF RFID (922~928 MHz) bands. The measured peak gain and radiation efficiency are about 6.2 dBic and 90% across the operating band, respectively, with unidirectional pattern in the XZ- and YZ-plane.

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