

Compact UHF Near-Field RFID Reader Antenna

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Abstract - A compact dual open-loops antenna with bandwidth enhancement is proposed for near-field operations in the ultra-high frequency (UHF) band, which is able to generate a strong and uniform magnetic field in a near-field zone of the smaller open-loop. The two open-loops with individual half-wavelength perimeters are etched on each sides of FR4 printed circuit board and used for widening bandwidth. The fabricated compact antenna with an overall size of a dimension of $60 \times 60 \times 0.8 \text{ mm}^3$, achieves an interrogation zone of $50 \times 50 \text{ mm}^2$ with good impedance matching and uniform magnetic field distribution over the bandwidth of 888-932 MHz. The measured reading distance of the proposed antenna is up to 130 mm for near-field applications, and it confirmed that the antenna is suitable for handheld radio frequency identification (RFID) reader applications.

Index Terms — Open-loop antenna, UHF RFID, Near-field coupling, Reader applications.

I. INTRODUCTION

An UHF RFID system generally consists of a reader and a tag. A reader with an antenna sends a radio frequency signal to a tag and receives a backscattered signal from the tag. The RFID reader antenna is one of the important components in RFID system and has been designed with circular polarization for far-field operation or with magnetic (inductive) coupling between the reader and the tag antenna for near-field communications. Recently, UHF near-field RFID systems have gained much attention owing to the promising item-level applications for garments, drugs, liquid objects and retail industries [1, 2]. These near-field RFID systems need a special reader antenna that can generate a strong and uniform magnetic field in the near region of the antenna. A typical technique for the inductive coupling, conventional loop structures have been used as reader antenna in UHF band [3, 4]. Generally, a loop antenna with a perimeter much less than its operating wavelength can be considered as a small loop, which has current in-phase along the loop and produces a uniform magnetic field in the region around the loop. Some structures use a segmented loop [5, 6], which is to divide the loop into short segments and use capacitive coupling between each pair of segments to generate in-phase current along the loop. However, the segmented loop antenna has disadvantages of large size and the complicated capacitor design, and it is not easy to design a feeding port to match to a $50\text{-}\Omega$ input. In addition, two printed-dipoles structured a one-wavelength loop to produce in-phase current along the loop is also presented [7].

In most UHF near-field RFID applications, the coupling between the reader and tag antennas is inductive due to adopt loop structures. The mutual inductive coupling between these two loops is mainly affected by the area of the loops. Commonly, a loop antenna with a perimeter less than $\lambda/2\pi$ (λ is the operating wavelength) can produce strong and uniform magnetic field in the near region of the loop because of the in-phase current along the loop, as shown in Fig. 1a. When the size of the loop closes to about half-wavelength perimeter, it will has in-phase current and uniform magnetic field distribution as shown in Fig. 1b. However, when the loop size becomes comparable to one-wavelength perimeter, the current has two nulls and reverse direction along the loop. In this case, the magnetic field distribution is no longer uniform at the center region of the loop, also as shown in Fig. 1c.

In this letter, a novel and compact dual-open-loops antenna fed by a simple capacitive coupling port was designed to obtain in-phase current and uniform magnetic field along the antenna. The excitation mechanism of the proposed antenna is the two open-loops capacitive fed by two strip-ports at the same time to widen the bandwidth. The proposed antenna shows a small size of half-wavelength perimeter and strong uniform magnetic field distribution around the loop. The measured maximum read range was up to 130 mm under a 30 dBm transmission power when the button near-field tag was attached to a water container.

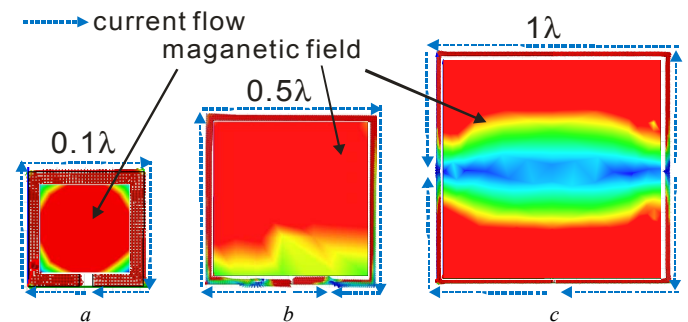


Fig. 1 Simulated current flow and magnetic field distribution ($H_z, z = 0 \text{ mm}$) at 915 MHz. (a) 0.1λ -perimeter loop, (b) 0.5λ -perimeter loop, (c) 1λ -perimeter loop.

II. ANTENNA DESIGN

The configuration of the proposed antenna is shown in Fig. 2, in which two square loops with the same strip width of 1.5 mm are etched on each side of square FR4 substrate, the

substrate has dimension of $60 \times 60 \text{ mm}^2$, thickness of 0.8 mm and dielectric constant 4.4. The two square loops are cut a pair of gaps (set to 1 mm) symmetrically with respect to the x-axis. A pair of inverted-L strips is etched on the top side of the substrate for feeding ports, which is used to couple electromagnetic energy to the opposite sides of open-loops at the same time and used as impedance matching stubs. The desired impedance matching can be obtained easily by adjusting the length of the inverted-L stubs. The proposed antenna with final optimal dimensions given in Fig. 2 is fabricated and tested.

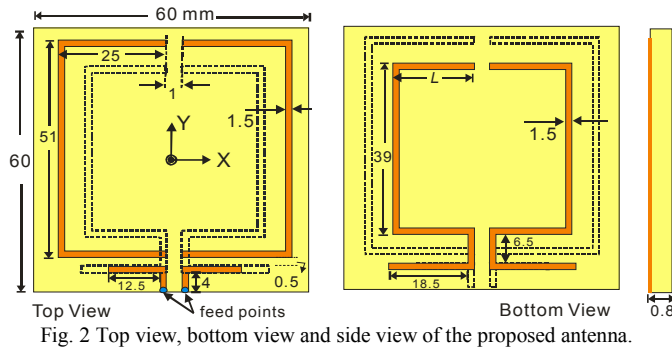


Fig. 2 Top view, bottom view and side view of the proposed antenna.

III. RESULTS AND DISCUSSIONS

The proposed compact antenna was designed to operate at the center frequency of about 915 MHz in near-field RFID reader. The return loss is measured using an Agilent N5230A vector network analyzer. Fig. 3 shows the simulated and measured return loss of the proposed antenna, which has broad impedance bandwidth owing to the dual open-loops. The measured bandwidth for 10 dB return loss is about 44 MHz, from 888 to 932 MHz or 4.8% around the center frequency of 915 MHz, and agrees well with the HFSS simulated results (895-932 MHz). For the above mentioned that the proposed antenna is able to produce strong and uniform magnetic field distribution around the near zone of the small loop. To measure the near-field z -component of the magnetic field (H_z) as a function of the distance on xy -plane, a small loop probe with a diameter of 4 mm is used as a near-field magnetic detector. The associated coupling coefficient between the proposed transmitting antenna and receiving probe are detected by using spectrum analyzer and compared to those results obtained from the simulations. In this case, the antenna surface lies on the xy -plane, and the measured plane was set to $z = 5 \text{ mm}$ which was the same plane with the simulation. Fig. 4 presents the measured magnetic coupling coefficient at 915 MHz for different positions of xy -plane and 3D plots. Fig. 4a exhibits the magnetic field distributions along the x - and y -axes, which are almost symmetrical with respect to both the axes. As be seen the measured coupling coefficients with a slightly variation at the central portion of the interrogation region ($-10 \text{ mm} < x, y < 10 \text{ mm}$) have a stronger and uniform distribution while the maximum magnetic field variation is about 16 dB over the range of $-40 \text{ mm} < x, y < 40 \text{ mm}$. The measured coupling coefficients for the xy -plane at $z = 5 \text{ mm}$ is 3D plotted in Fig. 4b which agree very well with simulation results. However, the proposed

antenna can generate approximate uniform magnetic field, and most of the interrogation region has sufficient field strength to read the near-field tags achieving a read range of up to 130 mm for a detection accuracy of 100%.

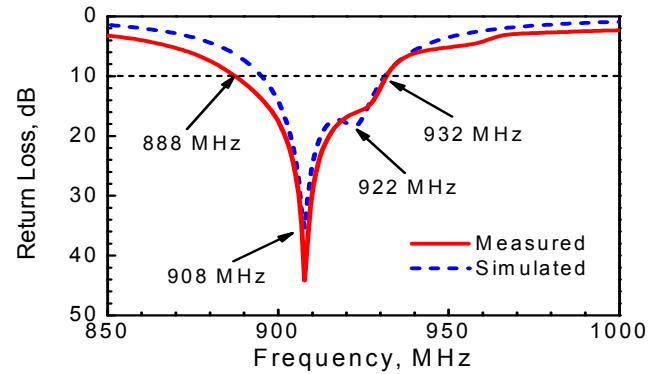


Fig. 3 Measured and simulated return loss of the proposed antenna.

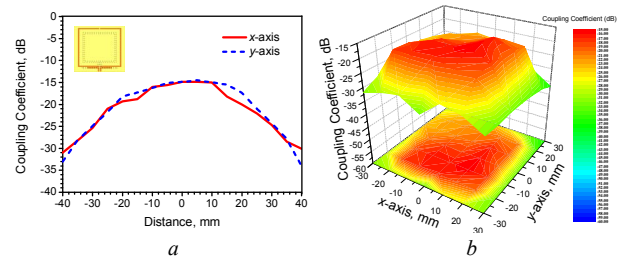


Fig. 4 Measured magnetic coupling coefficient of the proposed antenna at 915 MHz for $z = 5 \text{ mm}$. (a) xy -plane, (b) 3D surface plots.

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