Compact Near-Field Folded-Loop Antenna for UHF RFID Handheld Reader

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***Abstract* - A compact folded-loop antenna is proposed for near-field operations in the ultra-high frequency (UHF) band, which can be generated a strong and uniform magnetic field in a near-field zone of the folded-loop. The folded-loop with a one-wavelength perimeter is printed on the same side of FR4 substrate. The fabricated compact antenna with an overall size of a dimension of 50 × 50 × 0.8 mm^3, achieves a reading zone of 30 × 30 mm^2 with good impedance matching and uniform magnetic field distribution over the bandwidth of 919-932 MHz. The proposed antenna is suitable for handheld radio frequency identification (RFID) reader applications.**

***Index Terms* — Folded-loop antenna, UHF RFID, Near-field coupling, Handheld reader.**

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-Ω input. In addition, two printed-dipoles structured a one-wavelength loop to produce in-phase current along the loop is also presented [7].

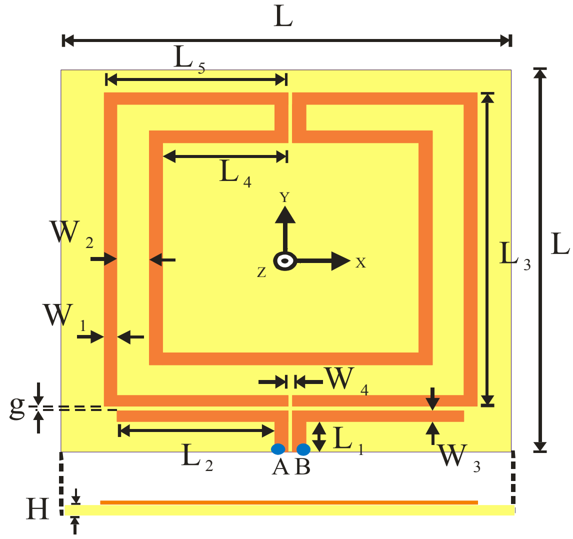


Fig. 1 The configuration of the proposed antenna.

TABLE I
THE OPTIMAL PARAMETERS OF THE PROPOSED ANTENNA

Parameter	Data (mm)	Parameter	Data (mm)
L	50	W_1	1.5
L_1	4.2	W_2	3.5
L_2	19	W_3	1.5
L_3	41	W_4	1
L_4	14	G	0.3
L_5	20.5	H	0.8

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. When the size of the loop closes to about half-wavelength perimeter, it also has in-phase current and uniform magnetic field distribution. 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. In this letter, a compact folded-loop antenna fed by a simple capacitive coupling port was designed to obtain in-phase current and uniform magnetic field along the antenna.

The proposed antenna shows a small size of one-wavelength perimeter and strong uniform magnetic field distribution around the near-field region of the loop. The measured maximum read range was up to 250 mm under a 30 dBm transmission power when the button near-field tag was attached to a water container.

II. ANTENNA DESIGN

The configuration of the proposed antenna is shown in Fig. 1, in which the folded-loop with a fixed width of 1.5 mm is printed on a square FR4 substrate, the substrate has dimension of 50 × 50 mm^2, thickness of 0.8 mm and dielectric constant 4.4. A pair of inverted-L strips is printed on the same side of the substrate for feeding ports, which is used to couple electromagnetic energy to the folded-loop 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 is listed in Table I.

III. RESULTS AND DISCUSSIONS

The proposed compact antenna was designed to operate at the center frequency of about 925 MHz in near-field RFID reader. The return loss is measured using an Agilent N5230A vector network analyzer. Fig. 2 shows the simulated and measured return loss of the proposed antenna. The measured bandwidth for 10 dB return loss is about 13 MHz, from 919 to 932 MHz or 1.4% around the center frequency of 925 MHz, and agrees well with the HFSS simulated results (918-932 MHz). Fig. 3a shows the simulated current flow along the folded-loop, which is unidirectional along the inner and outer loop. Fig. 3b shows resulting z-component of the magnetic field on the *xy*-plane above the antenna at z = 5 mm. It can be seen that the field distribution is uniform in the center region. To measure the near-field *z*-component of the magnetic field 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 mm which was the same plane with the simulation. Fig. 4 presents the measured magnetic coupling coefficient at 925 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 reading region (-20 mm < *x*, *y* < 20 mm) have a stronger and uniform distribution while the maximum magnetic field variation is about 20 dB over the range of -30 mm < *x*, *y* < 30 mm. The measured coupling coefficients for the *xy*-plane at z = 5 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 reading region has sufficient field strength to read the near-field tags achieving a read range of up to 220 mm for a detection accuracy of 100%.

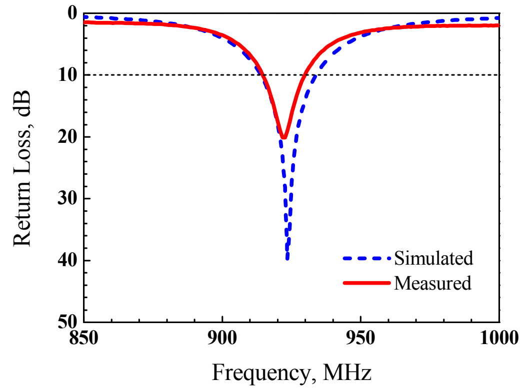
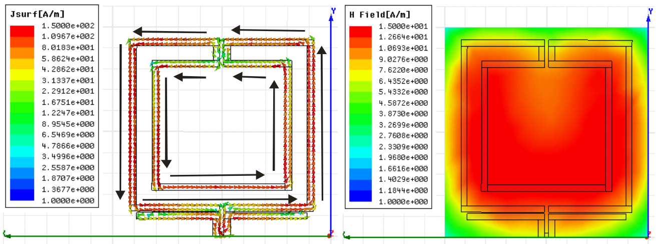
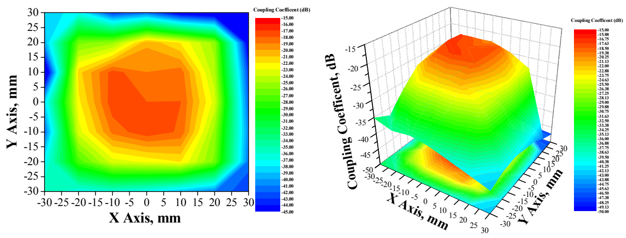


Fig. 2 Measured and simulated return loss of the proposed antenna.



a *b*

Fig. 3 Simulated current flow and magnetic field distributions of the proposed antenna.



a *b*

Fig. 4 Measured magnetic coupling coefficient of the proposed antenna at 925 MHz for z = 5 mm. (a) xy-plane, (b) 3D surface plots.

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