

UHF Near-field RFID Reader Antenna

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Abstract — A segmented loop antenna is presented for ultra high frequency (UHF) near-field radio frequency identification (RFID) applications. Even though the perimeter of the loop is comparable to the operating wavelength, the proposed segmented line configuration allows current along the loop to remain in phase so that a strong and uniform magnetic field is generated in the region surrounding the antenna. The antenna is printed on an FR4 printed circuit board (PCB) with an overall size of 160 mm × 180 mm × 0.5 mm. It achieves good impedance matching and uniform magnetic field distribution over an operating bandwidth of 800 – 1040 MHz which is desirable for UHF near-field RFID reader applications.

Index Terms — Antenna, near-field, RFID, UHF, loop antenna, segmented line.

I. INTRODUCTION

Radio frequency identification (RFID), which was developed around World War II, is a technology that provides wireless identification and tracking capability and is more robust than that of a bar code [1]–[2]. RFID can be used for example in identifying objects in warehousing, supply chain management, and other automation processes. In a typical passive RFID system, each individual object is equipped with a small and inexpensive tag (transponder) which comprises an antenna and an application specific integrated circuit (ASIC, or microchip) that is given a unique electronic product code [3]. The reader (interrogator) emits a signal to activate the tag, which passes through the electromagnetic zone generated by a reader antenna, and decodes the data encoded in the tag's microchip. The data is then passed to a host computer for processing. The querying signal coming from the reader must have enough power to activate the tag microchip, perform data processing, and transmit back a modulated string over a required reading distance.

Generally, the near-field RFID systems at low frequency (LF, 125–134 KHz) and high frequency (HF, 13.56 MHz) bands are based on inductive coupling to conduct power transfer and data transmission between the reader antenna and the tags. The far-field RFID systems at ultra-high frequency (UHF, 840–960 MHz) and microwave (2.4 GHz and 5.8 GHz) bands use electromagnetic waves propagating between the reader and tags. Currently, UHF near-field RFID technology receives a lot of attention due to the promising opportunities of item-level RFID applications in pharmaceutical and retailing industry [4]–[5], which spurs the investigation of the antennas for UHF near-field applications.

II. UHF NEAR-FIELD RFID READER ANTENNA DESIGN CONSIDERATIONS

Similar to LF/HF near-field RFID systems, the coupling between the UHF near-field RFID reader antennas and the tags can be either magnetic (inductive) or electric (capacitive). Inductive coupling systems are preferred in most applications since most reactive energy is stored in magnetic field. Because such systems are only affected by objects with high magnetic permeability, they are able to operate in close proximity to metals and liquids. On the other hand, capacitive coupling systems are hardly used in practical applications because the energy is stored in electric field which is severe affected by objects with high dielectric permittivity and loss. Fig. 1 shows a typical inductive coupling RFID system, where both the reader and tag antennas are loop (coil) antennas.

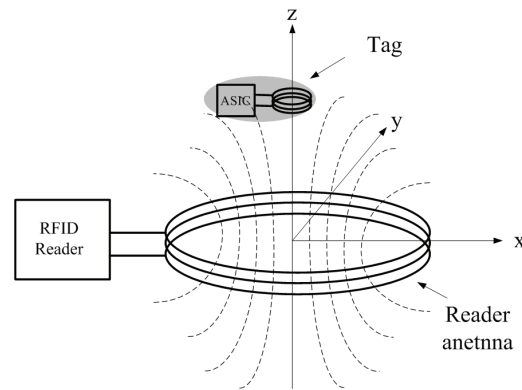
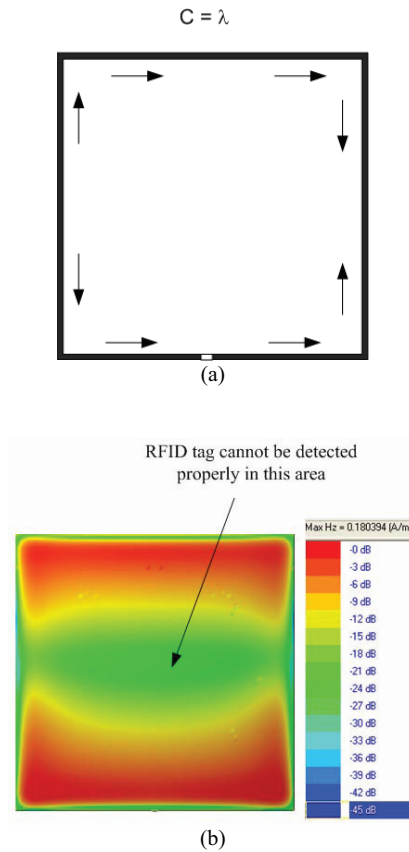


Fig. 1. Inductive coupling in near-field RFID systems.

The coupling coefficient between the antennas can be expressed as [6]

$$C \propto f^2 N_{tag}^2 S_{tag}^2 B^2 \alpha \quad (1)$$

where f is the frequency, N_{tag} is the number of turns in tag antenna coil, S_{tag} is the cross-section area of the coil, B is magnetic field density at the tag location created by the reader antenna, and α is the antenna misalignment loss.



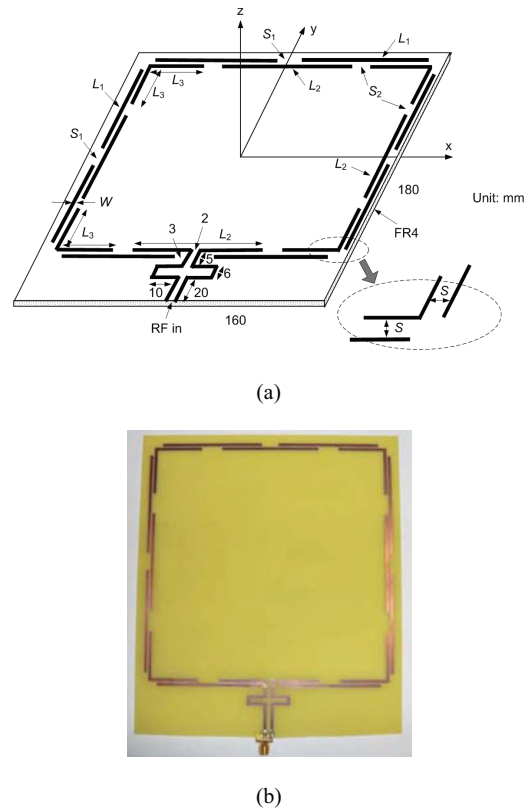
The conventional solid line loop antenna has been used as reader antenna in LF/HF RFID systems for many years since these electrically small loop antenna (i. e. the perimeter of the loop antenna $C < \lambda/2\pi$, where λ is the wavelength at the operating frequency) can produce strong and uniform magnetic field in the region near to the antenna. However, when the conventional loop is applied in the UHF band, its perimeter is comparable to the wavelength at the operating frequency, the electrically large (i.e. $C \geq \lambda$) loop antenna cannot produce uniform magnetic field because the current flow of the loop features current nulls and phase-inversion along the loop. As shown in Fig. 2(b), the antenna produces relatively weak magnetic field in the center region of the antenna. This compensates the reliability of tag detection.

The main design consideration of the reader antenna design for inductive coupling UHF near-field RFID applications is to allow the current along the loop to remain in phase and in a single direction flow, so as to produce

strong and uniform magnetic field distribution in the interrogation region [7-8].

III. ANTENNA CONFIGURATION

The scheme of the proposed segmented loop antenna printed on a PCB is shown in Fig. 3(a). A Cartesian coordinate system is oriented such that the upper surface of the FR4 PCB in Fig. 3(a) lies in the x - y plane. The antenna comprises multiple segmented line sections and matching stubs, which are symmetrically structured with respect to the centerline (y -axis) and printed on the same side of the FR4 PCB (thickness of $h = 0.5$ mm, relative dielectric constant of $\epsilon_r = 4.4$, and loss tangent of $\tan\delta = 0.02$). The segmented coupling line sections provide a very small phase delay between the adjacent sections so that the current flowing along the segmented lines is kept in a single direction. In other words, the current distribution on the segmented loop looks in-phase. Therefore, the segmented loop antenna produces uniform magnetic field distribution even though the loop is electrically large.



The proposed antenna is indicated with the main geometrical parameters as: L_1 and L_2 , the length of the outer / inner segmented line sections; S_1 and S_2 , the gap between the outer / inner series lines; S , the separation between the parallel lines, and W , the width of the lines. The single direction current flow along the loop antenna can be achieved by optimizing these parameters. The impedance matching between the antenna and the RFID reader can be achieved using an impedance matching circuit which can be realized using tuning stubs or lumped components.

IV. RESULTS

The antenna was designed with aid of the IE3D software which is based on the Method of Moments [9]. The dimensions of the antenna prototype shown in Fig. 3(b) are $L_1 = 60$ mm, $S_1 = 10$ mm, $L_2 = 58$ mm, $S_2 = 12$ mm, $L_3 = 24$ mm, $S = 0.5$ mm, and $W = 2$ mm. The other dimensions and the details of the matching stubs are illustrated in Fig. 3(a).

Fig. 4 compares the measured and simulated impedance matching of the proposed antenna, good agreement is observed. Broadband impedance matching is achieved. The 10 dB return loss bandwidth is 240 MHz (800–1040 MHz) which covers the entire UHF RFID band of 840–960 MHz.

Fig. 5 demonstrates the simulated current distribution of the proposed antenna at 860, 915, and 960 MHz. The single direction current flow along the closed segmented loop is observed at all the frequencies. Fig. 6 illustrates the magnetic field distribution at the frequencies of 860, 915, and 960 MHz. The uniform field distribution is achieved over the region which is enclosed by the antenna, no nulling area is observed, which is desired for RFID applications.

With an Impinj Speedway reader, the segmented antenna prototype can detect the Impinj button type tag (J21) at a maximum distance of 140 mm.

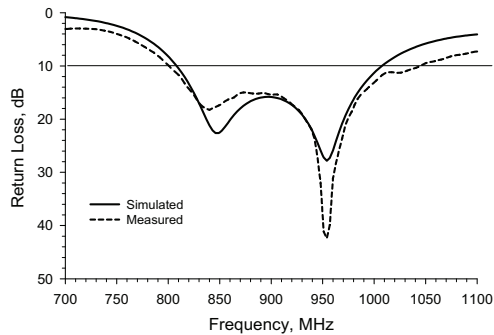


Fig. 4. Simulated and measured return loss of the proposed antenna.

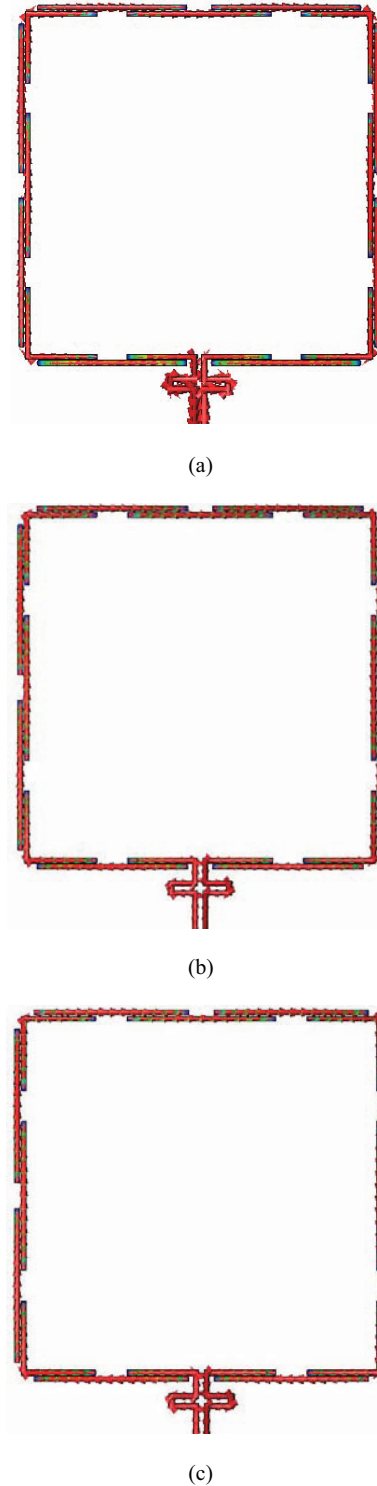


Fig. 5. Simulated current distribution of the proposed antenna at (a) 860 MHz, (b) 915 MHz, and (c) 960 MHz.

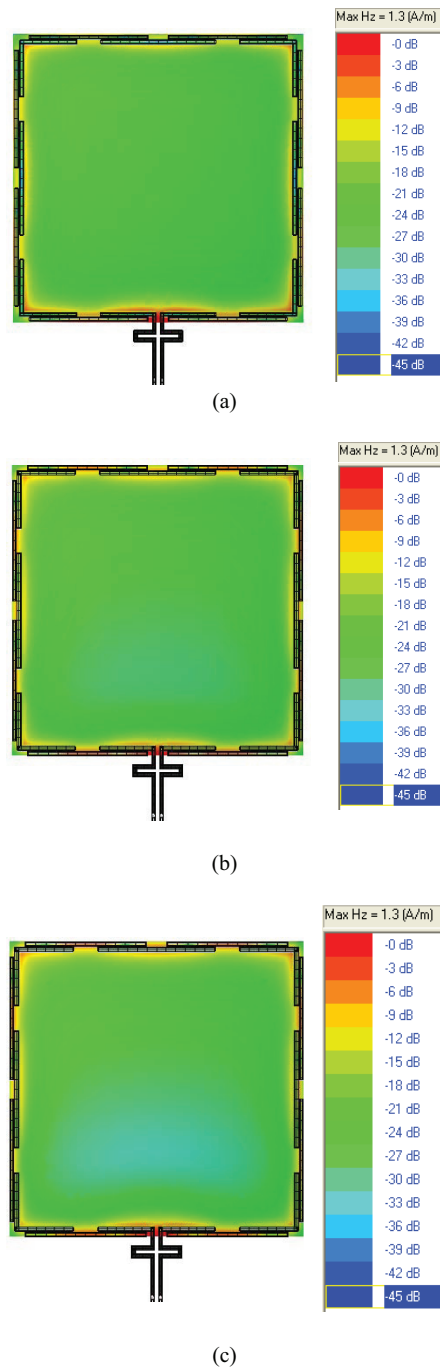


Fig. 6. Simulated magnetic field (H_z) distribution of the proposed antenna at (a) 860 MHz, (b) 915 MHz, and (c) 960 MHz.

V. CONCLUSION

It is a challenge to design an electrically large loop type antenna at an UHF band to generate uniform magnetic field distribution for near-field RFID applications. The key design consideration is to keep the single direction current flow along the loop when the loop is electrical large. The proposed segmented loop antenna has demonstrated the capability of producing strong magnetic field with relatively uniform field distribution. Such design is suitable for UHF near-field RFID reader applications.

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