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Design of loop antenna for near-field and far-field UHF RFID applications

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Abstract
Radio-frequency-identification (RFID) technology has received a lot of attention in warehouse, supply chain, industry, and commerce. As RFID deployment moves from pallet level to item level, it is necessary to identify and track objects by RFID tags at anytime and anywhere. Then, mobile RFID device has advantages in terms of cost, portability and wireless communication. By folded-dipole loop structure with parasitic element, a small antenna size can be achieved. The antenna with different parasitic element size can work on different UHF RFID bands. A novel type of radio frequency identification (RFID) reader antenna is proposed for mobile ultra-high frequency (UHF) RFID device. Effects of geometrical length, effect of width of strip, effect of ground plane length on of the frequency verses S parameters and gain of antenna are analyzed.

I. INTRODUCTION

Radio-frequency-identification (RFID) has played a major role for automated identifying and tracking objects in various applications, such as warehouse, supply chain, industry, and commerce. Generally, there are two kinds of RFID systems: far-field and near-field system. The far-field RFID systems only operate at UHF (1260-1300 MHz) bands with electromagnetic waves propagating between the readers and tags. Relatively, the near-field RFID systems are based on inductive coupling to transfer power and transmit data between the readers and tags. In near-field systems, the inductive coupling stores most of the reactive energy in the magnetic field near to the reader antenna region. In near-field system, the reader antenna will be only affected by high magnetic permeability objects and operates well in close proximity to metals and liquid. The near-field systems can operate at low frequency (LF, 125-134 kHz), high frequency (HF, 13.56 MHz) and UHF bands. The conventional LF/HF near-field RFID tag has complex multiturn loop structure, and the data transmission rate is lower compared to UHF near-field systems. Thus, RFID system for both near-field and far-field applications at UHF band simultaneously is drawing the world's attention

Mobile RFID device has advantages in terms of cost, portability and wireless communication. Mobile RFID device is defined as a compact RFID reader into a mobile phone, which provides diverse services through mobile communication networks. Anyone with mobile RFID device can directly identify RFID tags attached object, and access cloud computing with 3G/Wi-Fi communication network for searching, verifying, and managing object information. Mobile RFID has been a rapidly growing RFID technology for item-level tagging (ILT) in different applications, such as pharmaceutical and retailing industry

However, the challenge of mobile RFID is that the mobile reader antenna must have both near-field and far-field RFID operation for various applications. Inductively coupled near-field operation is usually used for objects surrounded by metals or liquids. Then electromagnetically far-field operation is commonly used to achieve long reading range. The typical UHF RFID reader antenna works with pure far- field characteristic. Recently, a few UHF reader antennas have been considered with pure near-field characteristic. But there are few papers about antenna for both near-field and far-field UHF operations, and they all have too large size to use in mobile. In this project, the loop antenna for near-field and far-field UHF RFID applications is being proposed.

The antenna can operate on India Band, Europe Band, China Band and Japan Band, by modifying the parasitic element parameters. Loop antennas feature simplicity, low cost and versatility. They may have various shapes: circular, triangular, square, elliptical, etc. They are widely used in communication links up to the microwave bands (up to ≈ 3 GHz). They are also used as electromagnetic (EM) field probes in the microwave bands.

Loop antennas are usually classified as electrically small ($C < 0.1\lambda$) and electrically large ($C \sim \lambda$). Here, *C* denotes the loop's circumference. Their radiation resistance can be substantially improved by adding more turns. Multi-turn loops have better radiation resistance although their efficiency is still poor. That is why they are used mostly as receiving antennas where losses are not so important. The radiation characteristics of a small loop antenna can be additionally improved by inserting a ferromagnetic core. Radio-receivers of AM broadcast are usually equipped with ferrite-loop antennas. The small loops, regardless of their shape, have afar-field pattern very similar to that of a small electric dipole (normal to the plane of the loop). This is expected because they are equivalent to a magnetic dipole. Note, however, thatthe field polarization is orthogonal to that of the electric dipole.

As the circumference of the loop increases, the patternmaximum shifts towards the loop's normal, and when $C \approx \lambda$, the maximum of the pattern is at the loop's normal.

A small loop is a loop of constant current whose radius satisfies

$a < (\lambda/6\pi)$

Whose circumference *C* satisfies

$C < (\lambda/3)$

to make sure that the current has constant distribution along the loop, a tighter limit must be imposed

$a < 0.03\lambda$ or $C < (\lambda/5)$

the far-field components when the loop's normal is along the *z*-axis

$E\phi = \{\eta\beta^2 .(IA).e^{-j\beta r}.\sin\theta\} / (4\pi r)$

$H\phi = \{-\beta^2 .(IA).e^{-j\beta r}.\sin\theta\} / (4\pi r)$

It is obvious that the far-field pattern,

$E\phi(\theta) = \sin\theta$

Radiated power:

$\Pi = \iint (|E\phi\ .\ |^2 r^2 .\mathrm{Sin}\theta\, d\theta\, d\phi) / 2\eta$

$\Pi = \{\eta\beta^4 .\ (IA)^2\}/12\,\pi$

Radiation resistance:

$R^r = \eta.(8/3).\pi^3 (A/\lambda^2)^2$

In free space,

$\eta = 120\pi\ \Omega$

And $R^r = 31171(A/\lambda^2)^2$

II. ANTENNA DESIGN AND STRUCTURE

A novel folded-dipole antenna with parasitic element is proposed, as shown in Fig. 1. The bent folded-dipole forms a large outer loop with a split, and two C-type arms combine a small inner loop with two splits. The antenna geometry was designed on a 1.6 mm thick low-cost substrate with $\varepsilon_r = 4.4$ and the whole antenna size is L1 (31 mm) × L1 (31 mm). The dimension of the proposed antenna is as shown in Table 1.

Parameter	Size (mm)	Parameter	Size (mm)
L1	31.0	W1	1.0
L2	29.0	W2	1.5
L3	22.0	W3	4.2
S1	1.0	W4	0.9
S2	2.0	W5	4.5
S3	1.0	G1	1.0
		G2	2.0

One of the advantages of folded-dipole loop is that the input impedance can be adjusted by the parasitic element.

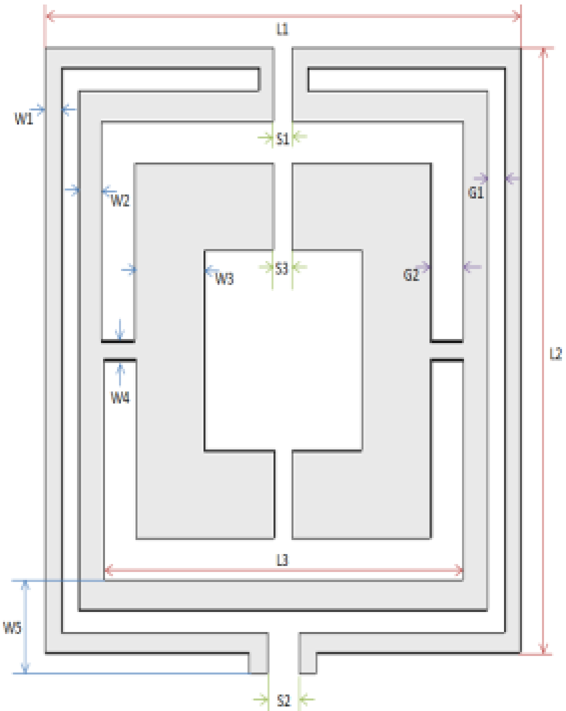

Fig.1 Antenna geometry

III. SIMULATION SOFTWARE

The design was optimized using electromagnetic simulation with the COMSOL Multiphysics software. The design goal was to maximize the bandwidth. The main reason for choosing COMSOL Multiphysics is that it is a flexible platform that allows users to model all relevant physical aspects of their designs andit helps to evaluate and optimize their antenna designs to achieve the best device performance.

IV. SIMULATION RESULTS

Fig. 2 shows the simulated SWR against frequency by varying the C-type arm parameters. By decreasing the width W4 or split s3, the input resistance and reactance curve are both shifted to lower frequency. By increasing the width W4 or split s3, the input resistance and reactance curve are both shifted to higher frequency.

Figure 3 presents the Electric field distribution of the proposed and conventional antenna. It can be seen that in-phase current is flowing along the folded dipole loop and most edge of parasitic loop, except the current at the lower edge of parasitic loop. Though the current at the lower edge of folded dipole-loop is at least double larger in amplitude relative to that of parasitic loop. The parasitic element significantly lowers resonance frequency of the folded-dipole loop. Compared to the conventional antenna, the proposed antenna in Fig. 1 and Table 1 has an enough bandwidth for India RFID Band (1260-1300 MHz), with s3 = 1.0 mm, and W4 = 0.9 mm. This antenna is also suitable for Korea RFID Band (917–924 MHz) and Australia RFID Band (918– 926 MHz). When the split s3 lowers to 0.5 mm, the antenna will operate well on Europe RFID Band (865–868 MHz). However, if the width W4is enhanced with a larger value of 6.7 mm, the bandwidth of antenna will completely cover Japan RFID Band (950–956 MHz). Therefore, the proposed antenna can be customized for different RFID bands by varying the parasitic element parameters.

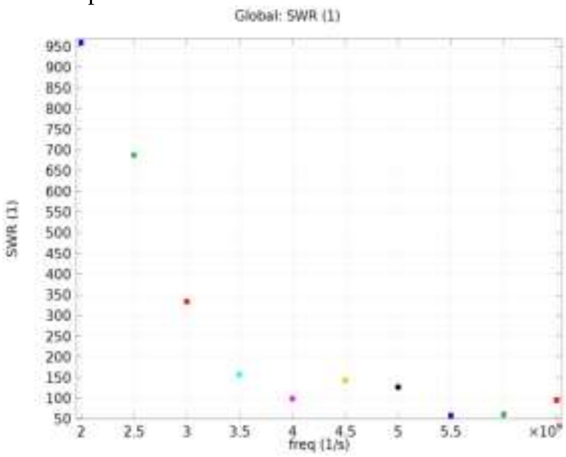

Fig.2 : 1D Plot Group 4

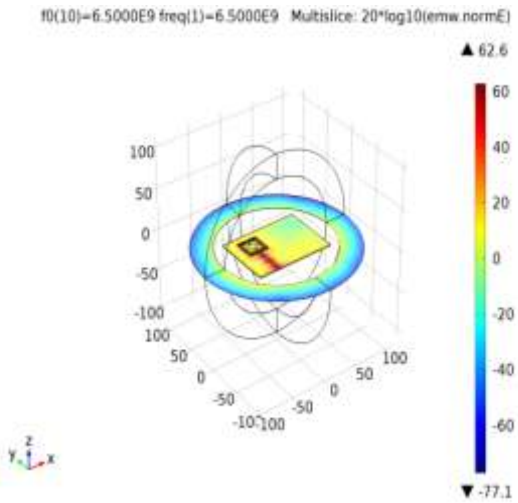

Fig. 3 : Electric Field (emw)

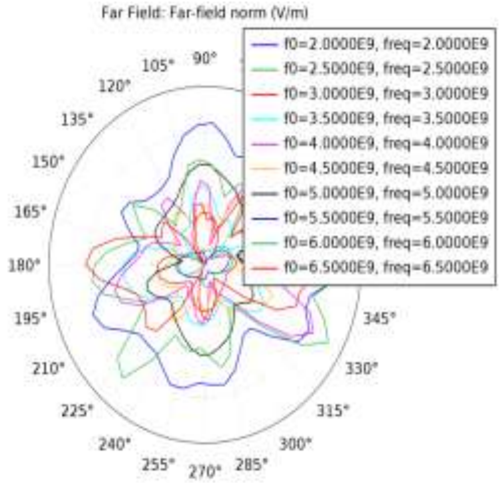

Fig. 4 : Polar Plot Group 2

V. CONCLUSION

The proposed antenna composed of a segmented loop antenna and a patch is suitable for applications Near Field and Far Field UHF RFID. The interference of the current distribution on the two antennas. It was necessary to incorporate physical constraints into the simulation model, in order to determine the best antenna design.. The antenna is simulated through comsol simulation tool; the software used to design antennas.Finally, the antenna prototype, with a compact size of $31*31*1.6$ mm^3, can cover the India RFID band (1260-1300 MHz) completely. With a near field button-type RFID tag, the maximum read range can be obtained. The near-field reading performance should not degrade when the RFID tag is placed on different objects (liquid, paper, fruit surface and human body). On the other hand, the far-field reading range, with a common dipole RFID tag, is seriously affected by surrounding. Such an antenna design has suitable near-field and far-field performance for mobile UHF RFID application.

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