Design of an RFID Reader Antenna for Near-Field Communications Using Opposite-directed Currents

Chihyun Cho*, Jeongki Ryoo**, Ikmo Park***, and Hosung choo*
*School of Electronic and Electrical Engineering, Hongik University
** Communication Research Lab., Central R&D Center, LS Industrial Systems
*** Department of Electrical and Computer Engineering, Ajou University
E-mail: hschoo@hongik.ac.kr

Abstract

In this paper we propose a novel near-field antenna for radio-frequency identification (RFID) based on the principle that two closely spaced opposite-directed currents (ODC) can generate a strong magnetic field over a broad surface area. To implement the ODC concept, the proposed antenna uses a symmetrical inverted-L structure with a parasitic patch. The proposed antenna provides an H_z field greater than –20 dBA/m in a region of 30 × 30 cm^2. Tests of the antenna with a commercial RFID system show a maximum reading range of 20 cm, and a reading area of 136 cm^2 for a reading range greater than 10 cm.

Introduction

Radio-frequency identification (RFID) systems for ultra-high frequency (UHF) near field communications are increasingly popular for item-level tagging since the tag can be detected more consistently on various target objects such as bottles of water, clothes, and small items [1–3]. A reader antenna that can generate a strong magnetic field is required for near field RFID applications. For example, identifying a tag with a commercial Gen2 micro-chip and a loop antenna of 0.5-cm radius requires an H_z field of at least –20 dBA/m. In addition, the H_z field should be uniformly distributed to remove nulls in the reading zone and increase the reading stability. In this paper, we propose a novel near-field reader antenna that can achieve a strong and uniformly distributed H_z field by using the concept of opposite-directed currents (ODCs). The fabricated antenna provided an H_z field of greater than –20 dBA/m in a 30 × 30 cm^2 region. Our measurements showed a maximum reading range of 20 cm, and a reading area of 136 cm^2 for a reading range greater than 10 cm.

Antenna Structure and Characteristics

We designed a near-field antenna using the concept of two closely spaced ODCs that can generate a strong magnetic field over a broad surface area. The distribution and strength of the near magnetic field produced by the ODCs can be easily controlled by tuning the amplitude, length, and location of each current. Figure 1 shows the design of the near-field reader antenna. A symmetrical inverted-L structure is used produce a current similar to a half-wavelength dipole. One end is fed by coaxial cable and the other end is shorted to a ground plane. A parasitic patch is inserted in the vicinity of the symmetric inverted-L to obtain the ODC. When the distance between the symmetric inverted-L and the parasitic patch is about 0.15 λ, the current in each conducting body will be in opposite directions, i.e., out of phase. The conducting part of the antenna was printed on an FR-4 substrate to keep the cost low. The detailed design parameters such as the height and length of the inverted-L antenna, the size of the parasitic patch, and their locations were optimized using the Pareto genetic algorithm (PGA) in conjunction with FEKO EM simulators [4, 5]. In the optimization process, we used two cost functions. Cost1 was for maximizing the near H_z field and Cost2 was for obtaining a uniform distribution of the H_z field.

$$\mathrm{Cost1} = 1 - \sum_{n=1}^{N}\sum_{m=1}^{M}\mathbf{H_z}(x_n, y_m)$$

$$\mathrm{Cost2} = \max(\mathbf{H_z}) - \min(\mathbf{H_z})$$

where $\mathbf{H_z}$ (x_n, y_m) indicates the near magnetic field at the 30 × 30 cm^2 surface area greater than 10 cm above the antenna aperture. The optimized result using the PGA with the cost functions above is plotted as '▼' in Fig. 2. To examine the operating mechanism of each antenna part more closely, we also optimized the design without some antenna parts such as the shorted inverted-L ('●') and the parasitic patch ('■'). The results show that compared to the full design structure, a strong H_z cannot be obtained without the parasitic patch while uniform H_z cannot be obtained without the shorted inverted-L.

To confirm the optimized result, we built and measured the prototype shown in Fig. 2, marked as sample A. Figure 3 shows the H_z distribution of the prototype antenna 10 cm above the antenna aperture. The projected antenna structure is plotted as a dashed line in the same figure. The antenna had H_z greater than –20 dBA/m in the target reading area of 30 × 30 cm^2. We also measured the reading range using a commercial RFID system [6]. A simple near-field tag antenna with a rectangular loop of 1.0 cm × 1.5 cm was used for the tag with a commercial Gen2 micro-chip [7]. Our measurements showed a maximum reading range of 20 cm, and a reading area of 136 cm^2 for a reading range greater than 10 cm. Figure 4 shows the variation in the reading range when dielectric materials such as wood and water were placed between the reader and the tag antenna. The resulting reading range decreased to 20 cm as we increased the thickness of the wood up to 5.4 cm. This result is comparable to a reading range of 15 cm for the design without the parasitic patch in Fig. 2. The resulting reading range decreased to 12.5 cm when water replaced the wood; under the same conditions, the reading range of the design without the parasitic patch decreased to 11 cm.

Conclusions

In this paper we presented a novel RFID reader antenna for near-field UHF communications. The proposed antenna achieves a strong and uniformly distributed near magnetic field using the concept of opposite-directed currents. The fabricated antenna provided an H_z field greater than –20 dBA/m in a 30 × 30 cm^2 area. Our measurements showed a maximum reading range of 20 cm, and a reading area of 136 cm^2 for a reading range greater than 10 cm. The reading range was relatively consistent when various dielectric materials were placed near it. Our results confirm that the proposed antenna is suitable as a near field UHF antenna.

References

[1] P. V. Nikitin, K. V. Rao, and S, Lazar, "An overview of near field UHF RFID," *IEEE International Conference on RFID*, pp. 167–174, March 2007.

[2] J. Choo, J. Ryoo, I. Park, J. Hong, and J. Lee, "A novel multi-loop tag for near field communication in UHF band," *Proceeding of Asia-Pacific Microwave Conference*, pp. 1–4, December 2007.

[3] A. Shameli, A. Safarian, A. Rofougaran, M. Rofougaran, J. Castaneda, and F. De Flaviis, "A UHF near field RFID system with fully intergrated transponder," *IEEE Trans. Microw. Theory Tech.*, vol. 56, pp. 1267–1277, May 2007.

[4] FEKO Suite 5.3. in [Online]. Available at www.feko.info

[5] H. Choo, R. Rogers, and H. Ling, "Design of electrically small wire antennas using a Pareto genetic algorithm," *IEEE trans. Antennas Propag.*, vol. 53, pp. 1038–1046, March 2005.

[6] CS461 RFID reader. [Online]. Available at www.convergence.com.hk

[7] Impinj RFID chips. [Online]. Available at www.impinj.com

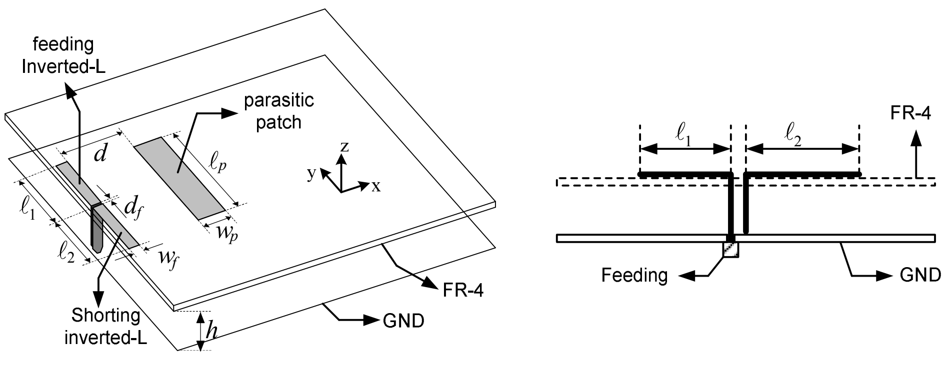

Figure 1. Geometry of the proposed antenna.

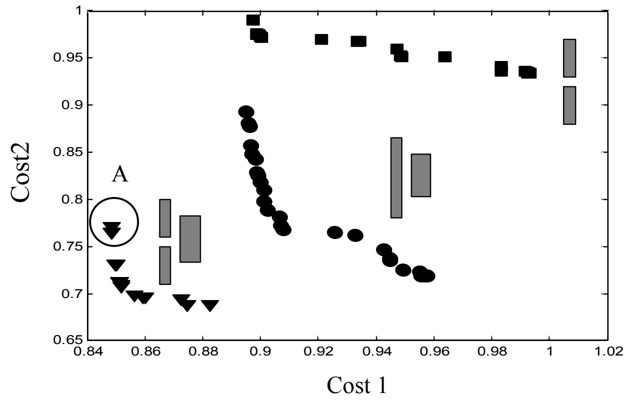

Figure 2. Optimized result for the proposed antenna.

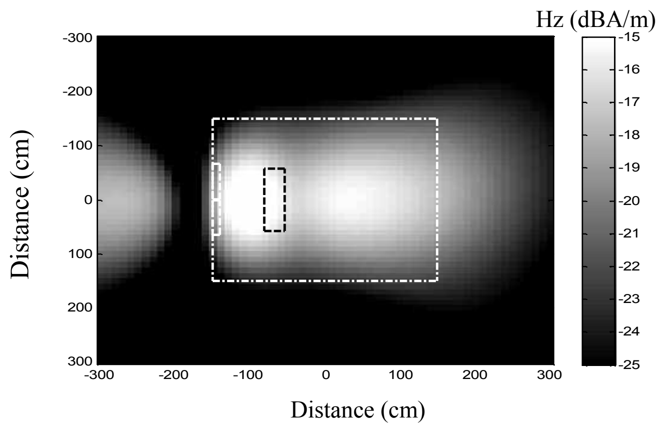

Figure 3. H_z field distribution of sample A.

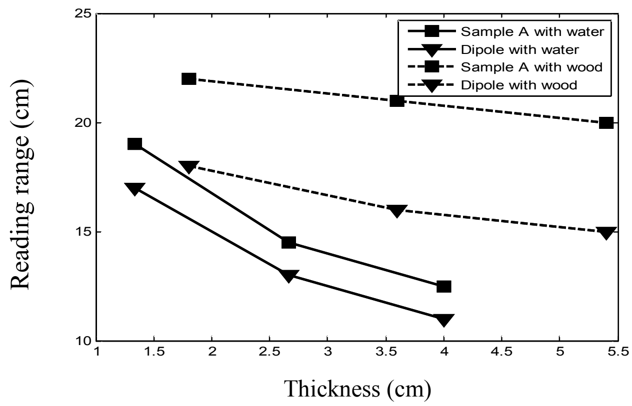

Figure 4. Variation of the reading range caused by nearby dielectric materials.