Planar Near-Field RFID Reader Antenna Using Opposite-directed Currents

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ABSTRACT: In this paper we propose a novel planar 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 dipole and a parasitic patch with a microstrip feedline. The proposed antenna provides an H_z field greater than –20 dBA/m in a region of 30×30 cm^2. Measurements with a commercial RFID system show a maximum reading range of 24 cm, and a reading area of 744 cm^2 for a reading range greater than 5 cm.

INTRODUCTION

Radio-frequency identification (RFID) systems for ultra-high frequency (UHF) near field communications have been widely used 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 [1–4]. Unlike systems for far field communications, the near field RFID dominantly uses the magnetic field in order to transfer RF power to passive tags, and therefore the 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 planar 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 24 cm, and a reading area of 744 cm^2 for a reading range greater than 5 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. Fig. 1 shows the design of the near-field reader antenna. A dipole structure is used produce a current similar to a half-wavelength dipole. A parasitic patch is inserted in the vicinity of the dipole to obtain the ODCs. When the distance between the dipole 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. Both of the dipole and the parasitic patch are fed by a microstrip feedline. The conducting part of the antenna and the feedline were printed on an FR-4 substrate to keep the cost low. The detailed design parameters such as the height and length of the dipole, the size of the parasitic patch, and their locations were optimized using the Pareto genetic algorithm (PGA) in conjunction with FEKO EM simulators [5, 6]. 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.

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

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

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. And the optimized antenna parameter is summarized in Tab. 1. To examine the operating mechanism of each antenna part more closely, we also optimized the design without some antenna parts such as 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 parasitic patch.

To confirm the optimized result, we built and measured the prototype shown in Fig. 2, marked as a circle. Fig. 3 shows the measured reading range of the proposed antenna using a commercial RFID system [7]. 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 [8]. Our measurements showed a maximum reading range of 24 cm, and a reading area of 744 cm^2 for a reading range greater than 5 cm. Fig. 4 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. Fig. 5 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 18 cm as we increased the thickness of the wood up to 5.4 cm. This result is comparable to a reading range of 11 cm for the design without the parasitic patch in Fig. 5.
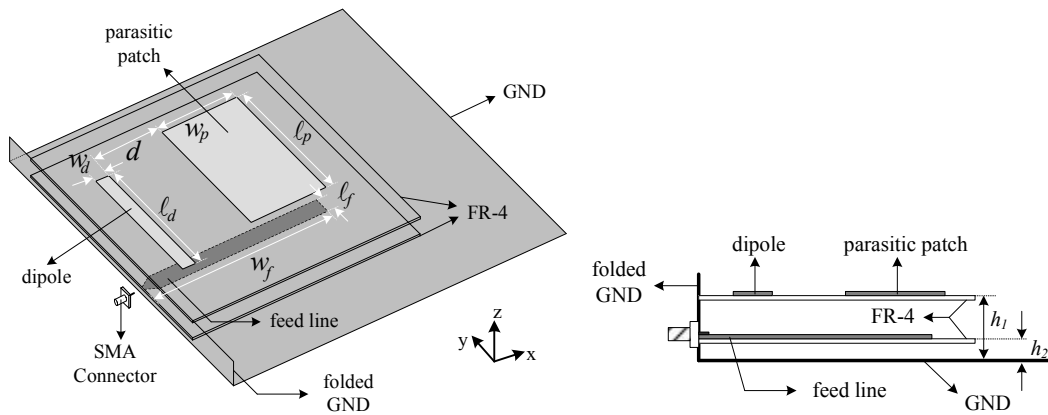
**Fig. 1. Geometry of the proposed antenna.**
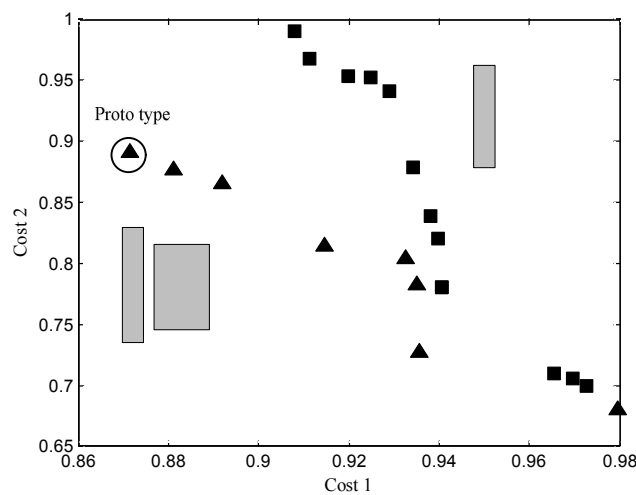
**Fig. 2. Optimized result for the proposed antenna.**

The resulting reading range decreased to 14 cm when water replaced the wood; under the same conditions, the reading range of the design without the parasitic patch decreased to 9.5 cm. This result clearly shows that the proposed antenna is less affected from the near dielectric materials compared to the dipole type reader antenna.

CONCLUSIONS

In this paper we presented a novel planar 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 24 cm, and a reading area of 744 cm^2 for a reading range greater than 5 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.
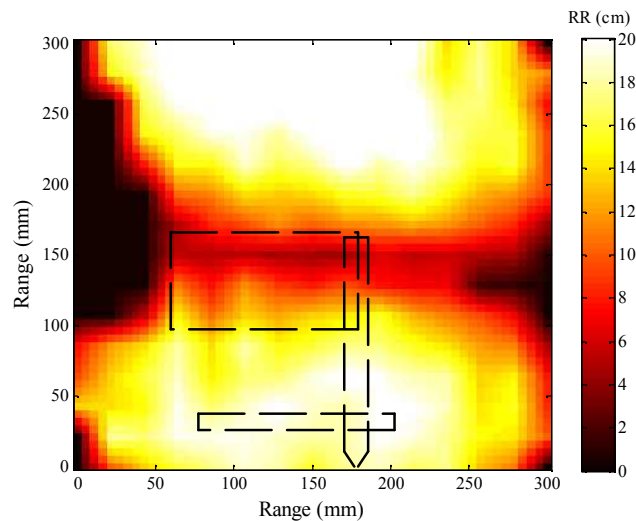

Fig. 3. Reading range of the proposed antenna.
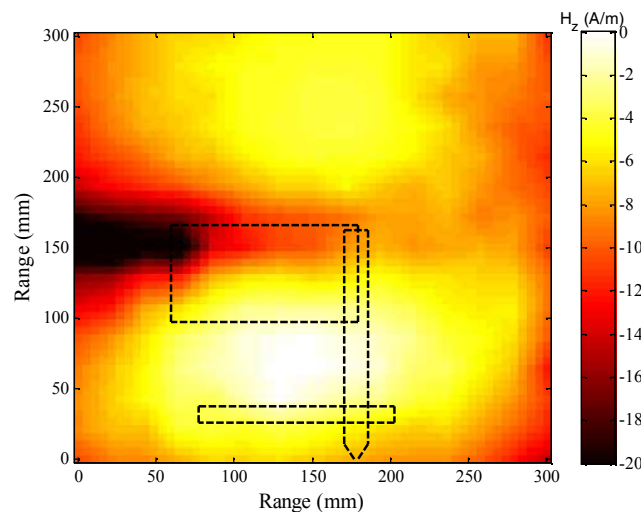
Fig. 4. H_z field distribution of the proposed antenna.

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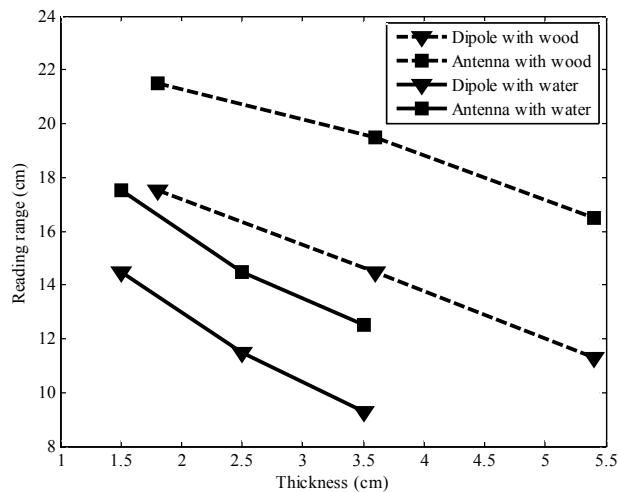
Fig. 5. Variation of the reading range caused by nearby dielectric materials.

Table 1. Design parameters of the antenna

Parameter	ℓ_d	ℓ_f	ℓ_p	w_d	w_f	w_p	d	h_1	h_2
length (mm)	125.1	162.1	119.9	11.4	15.3	68.6	58.9	24.2	6.4