An RFID Tag Using a Planar Inverted-F Antenna Capable of Being Stuck to Metallic Objects

Wonkyu Choi, Hae Won Son, Ji-Hoon Bae, Gil Young Choi, Cheol Sig Pyo, and Jong-Suk Chae

ABSTRACT—This letter presents the design for a low-profile planar inverted-F antenna (PIFA) that can be stuck to metallic objects to create a passive radio frequency identification (RFID) tag in the UHF band. The designed PIFA, which uses a dielectric substrate for the antenna, consists of a U-slot patch for size reduction, several shorting pins, and a coplanar waveguide feeding structure to easily integrate with an RFID chip. The impedance bandwidth and maximum gain of the tag antenna are about 0.3% at 914 MHz for a voltage standing wave ratio (VSWR) of less than 2 and 3.6 dBi, respectively. The maximum read range is about 4.5 m as long as the tag antenna is on a metallic object.

Keywords—RFID, tag antenna, PIFA.

I. Introduction

Radio frequency identification (RFID) has been widely used recently in supply chain and logistics applications in identifying and tracking goods. In RFID systems, tags are attached to objects varying in shape and material. A data transfer between a tag and reader is carried out by a backscattering of electromagnetic waves. That is, a tag partially rectifies electromagnetic waves from a reader and uses it as a power source. Then, the tag sends a coded signal back to the reader, backscattering a portion of the electromagnetic waves by means of load modulation. It is the antenna that determines the performance of a tag stuck to a specific object. Therefore, it must be designed and optimized for the materials and locations of objects it will be attached to. A lot of tag antennas have been developed depending on materials to which they are meant to be attached. One of the biggest challenges is to design a tag antenna capable of being stuck to conductive objects, for instance cans and aluminum foil, because such metallic surfaces can negatively affect the performance of an antenna, such as in resonant frequency and radiation efficiency [1]. The tag antenna for RFID systems should also be small in size, have a low profile, and be inexpensive to manufacture. Recently, dipoles with a meander line or folded dipoles printed on a film have been widely studied to comply with these requirements. However, these kinds of antennas are not suited to be attached to metallic objects. A planar inverted-F antenna (PIFA) or microstrip patch antenna is an attractive choice for tagging metallic objects [2], [3]. This letter presents the characteristics of a PIFA for a passive RFID system to identify metallic objects. The proposed PIFA is designed by introducing a U-slot to the patch and by using a co-planar waveguide as a feeding structure.

II. Design of the Low-Profile Planar Inverted-F Antenna

This letter presents the design and performance of a low-profile planar inverted-F antenna (PIFA) for use as a tag for a passive RFID system. The designed PIFA can be mounted on metallic objects. A PIFA consists of a ground plane and radiating patch, as well as a feed wire and shorting plate respectively placed and connected between them. The PIFA is fed by a feed wire at the point where the wire connects to the ground plane. The addition of the shorting plate allows for a good impedance match to be achieved with the radiating patch, which is typically less than $\lambda/4$ long. In [4], it is shown that a single shorting plate can reduce the antenna size and improve the VSWR bandwidth. The size and aspect ratio of the radiating patch, the height of the radiating patch above the ground plane, the width and position of the shorting pin, and the feeding location have considerable impact on the performance of the PIFA. That is, the resonant frequency and relative impedance bandwidth of the PIFA is

Manuscript received Sept. 02, 2005; revised Nov. 21, 2005.

Wonkyu Choi (phone: +82 42 869 1723, email: wkchoi@etri.re.kr), Hae Won Son (email: hwson@etri.re.kr), Ji-Hoon Bae (email: baejh@etri.re.kr), Gil Young Choi (email: kychoi@etri.re.kr), Cheol Sig Pyo (email: cspyo@etri.re.kr), and Jong-Suk Chae (email: jschae@etri.re.kr) are with Telematics & USN Research Division, ETRI, Daejeon, Korea.

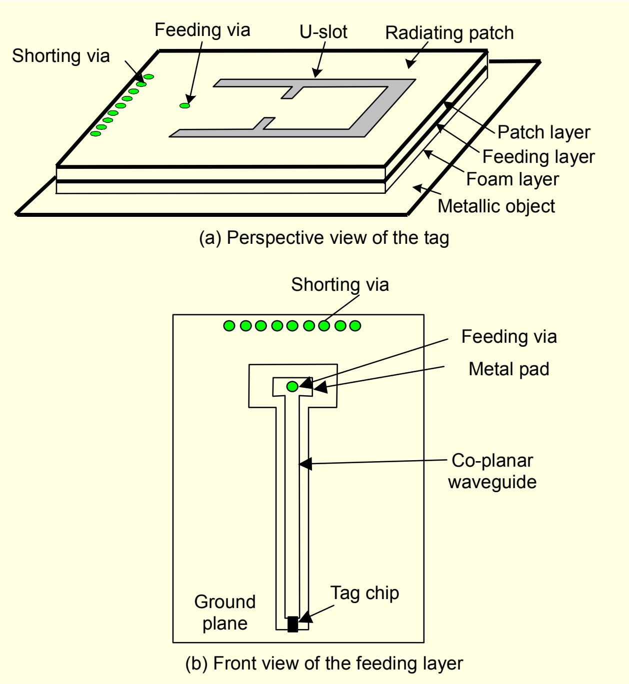

Fig. 1. Detailed configurations of the tag for an RFID.

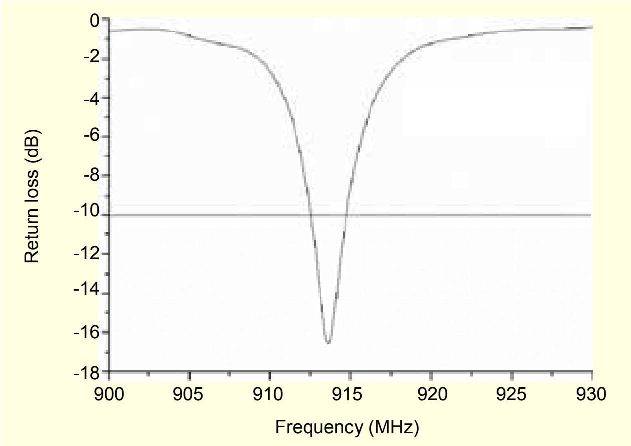

Fig. 2. Return-loss of the PIFA.

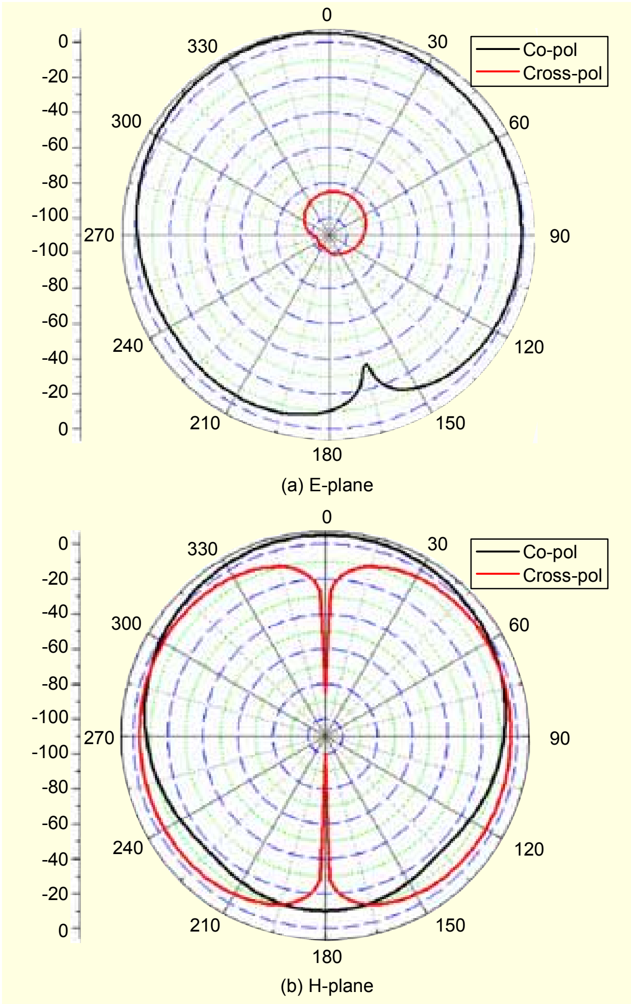

Fig. 3. Radiation patterns of the PIFA.

affected by the design of the structure. Therefore, the PIFA for an RFID tag must be designed considering the effects of the objects the PIFA will be attached to.

This letter proposes the configuration shown in Fig. 1 in order to obtain a low-profile PIFA capable of being attached to metallic objects for a tag of a passive RFID system. As seen in Fig. 1, the designed PIFA consists of a dielectric substrate with ε_r=2.5 and a thickness of 2.36 mm, and foam with ε_r=1.07 and a thickness of 1mm. Figure 1(a) shows the perspective of the designed tag. The PIFA is 46 mm × 46 mm in size with a height of 2.36 mm. Nine shorting vias are used for a short between the radiating patch and ground plane, and the distance between them is 3.25 mm. The resonant frequency and impedance match can also be tuned by simply adjusting the distance. In Fig. 1, the foam layer is used for insulation of the antenna from metallic objects. Figure 1(b) is the front view of the feeding layer of the designed PIFA. The PIFA has the feeding structure of the co-planar waveguide to integrate easily with a tag chip. The metal pad around the feeding via is used to tune the antenna impedance. The tag chip employed in this letter is a commercial product of Symbol Technologies, USA, and its input impedance is about 77–j100 Ω at 916 MHz.

III. Simulated Results of the Low-Profile Planar Inverted-F Antenna

Based on the geometry shown in Fig. 1, the results of the simulation using the commercial tool Microwave Studio are shown in Figs. 2 and 3. A metallic object to which the tag antenna is stuck is a copper board 200 mm × 200 mm in size. The input impedance of the PIFA is the complex conjugate of a commercial tag chip. Figure 2 shows the return-loss of the PIFA in which the impedance bandwidth for VSWR<2 is about 0.3%. The radiation patterns at 914 MHz are also shown in Figs. 3(a) and 3(b). These figures also show the co-polarization and cross-polarization in the E- and H-planes in which the cross-polarization level is lower than 80 dB for the broadside direction. The half power beamwidths are about 84° in both the E- and H-planes, and the radiation efficiency of the PIFA is nearly 75%. This efficiency is theoretically calculated using the commercial tool of the Computer Simulation Technology Microwave Studio.

IV. Measured Results of the Low-Profile Planar Inverted-F Antenna

In this letter, an RFID tag that can be attached to metallic objects is fabricated, and is comprised of a dielectric substrate and foam. Figure 4 shows a photograph of the fabricated PIFA for RFID tags. Figures 5 and 6 show the measured read ranges for different angles and frequencies, respectively. A commercial reader made by Symbol Technologies is used to measure the read ranges, which has a frequency hopping function in the range of 902.75 to 927.25 MHz and radiates up to 1 W. Figure 5 presents the read ranges of the tag on a copper board 200 mm × 200 mm in size for different angles. The maximum read ranges are 4.3 m at 0° in the E-plane and 4.9 m at -30° in the H-plane, while the operating frequency of the reader hops onto the frequency band in the range of 902.75 to 927.25 MHz. Figure 6 shows the read ranges in the E- and H-planes as a function of frequency. The read range at 914 MHz is about 3 m, and the maximum read range is about 4.5 m at 925 MHz.

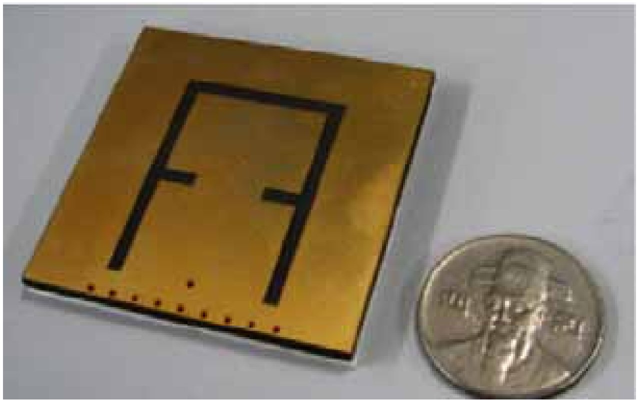

Fig. 4. Photograph of the fabricated PIFA.

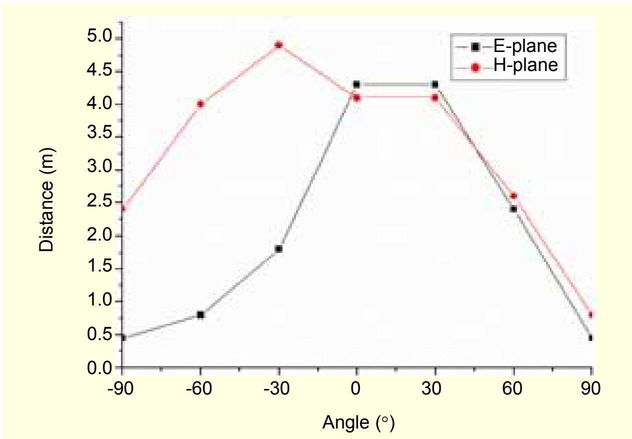

Fig. 5. Read ranges in E- and H-planes for different angles.

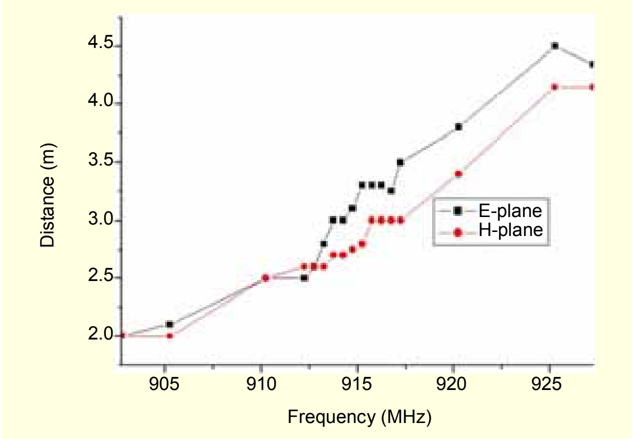

Fig. 6. Read ranges in E- and H-planes as a function of frequency.

V. Conclusion

This letter presents a low-profile planar inverted-F antenna(PIFA) to be used as a tag for a passive RFID system. The RFID tag using the proposed antenna can be used in identifying metallic objects. The read ranges of the tag on a copper board 200 mm × 200 mm in size for different angles and several frequencies are measured. Because it makes use of metallic surfaces, the designed antenna can be attached to metallic objects and operates within good read ranges.

Reference

[1] H. Nakano and K. Nakayama, "A Curved Spiral Antenna above a Conducting Cylinder," *IEEE Trans. Antennas and Propagation,* vol. 47, no. 1, Jan. 1999, pp. 3-8.

[2] L. Ukkonen, L. Sydanheimo, and M. Kivikoski, "A Novel Tag Design Using Inverted-F Antenna for Radio Frequency Identification of Metallic Objects," *Proc. 2004 IEEE/Sarnoff Symp. Advances in Wired and Wireless Communication,* Apr. 2004, pp. 91-94.

[3] W. Choi, Y. H. Cho, C. S. Pyo, and J. I. Choi, "A High-gain Microstrip Patch Array Antenna Using a Superstrate Layer," *ETRI J.*, vol. 25, no. 5, Oct. 2003, pp. 407-411.

[4] R. Chair, K. M. Luk, and K. F. Lee, "Simulation of Bandwidth Enhancement on the Quarter-wave Shorted Patch by Adding a Shorting Pin," *Int. Symp. IEEE AP-s,* vol. 1, 2001, pp. 82-85.